THE JANUARY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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The Scientific Monthly

An Illustrated Magazine Devoted to the Diffusion of Science

J. McKEEN CATTELL, Editor
WARE CATTELL, Associate Editor

Published by THE SCIENCE PRESS

LANCASTER, PA.—NEW YORK, N. Y., Grand Central Terminal—GARRISON, N. Y.
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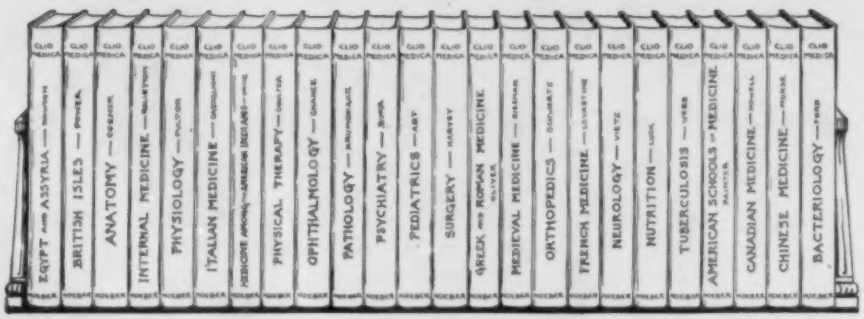

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JANUARY TO JUNE

NEW YORK
THE SCIENCE PRESS
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THE SCIENTIFIC MONTHLY

JANUARY, 1933

The Scientific Work of the Government of the United States

INTRODUCTION TO A SERIES OF ARTICLES ON THE RESEARCH ACTIVITIES OF THE FEDERAL GOVERNMENT

THE WHITE HOUSE
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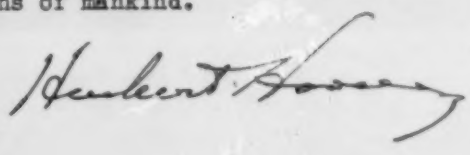
The insatiable curiosity of the human mind to probe the mysteries of Nature through scientific research into the operation of natural laws has resulted in such wealth of new inventions and new products, so satisfying to material needs of the people, that the world is irrevocably committed to an eternal quest of further truth, with certainty of endless and ever more rapid change as new knowledge is translated into new conveniences and comforts. The social relations of mankind have already been altered by these changes beyond the utmost imagination of our forefathers. Further and more revolutionary changes will be wrought.

As government is the art of social relations under recognized authorities set up by the will of the people, any change wrought by scientific advance quickly produces new problems of government. The Federal Government itself long ago sensed the potentialities of science when it gave official status to the Smithsonian Institution. From that pioneer body has flowed a stimulation to scientific research of the most valuable character, both directly in its own discoveries and indirectly through its leadership and inspiration of private institutions. Science is also recognized and encouraged by the Federal Government in the researches of the Department of Agriculture in biology, entomology, and other fields; and similarly in other Departments which promote research. Thus the Government still does, and increasingly should, lead the way by example toward the discovery of new knowledge to free mankind from ignorance, superstition, needless fears and poverty. Nor should it be unremarked that a spiritual value accrues in all this labor, for science requires a degree of unselfishness and devotion which calls out the finest qualities of the human spirit, and, since its goal is truth, the noblest aspirations of mankind.



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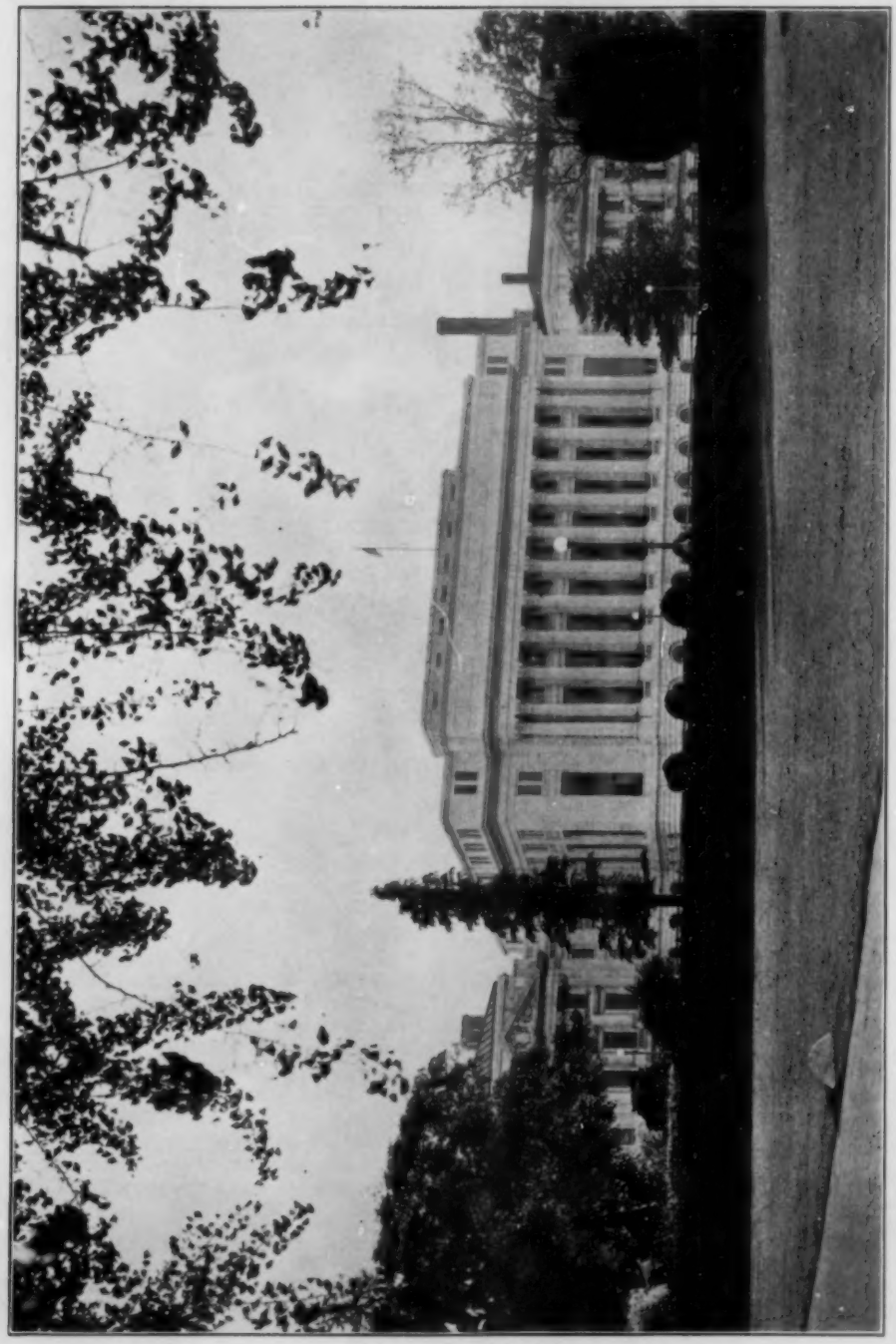


NEW ADMINISTRATION BUILDING OF THE U. S. DEPARTMENT OF AGRICULTURE, COMPLETED IN 1930, WITH THE EAST AND WEST WINGS, COMPLETED IN 1908.

RESEARCH IN THE UNITED STATES DEPARTMENT OF AGRICULTURE

By ARTHUR M. HYDE
SECRETARY OF AGRICULTURE

THE United States Department of Agriculture is an organic whole. It is not a loose bundle of unrelated activities. However unlike one another some of the parts may appear there is a golden thread which binds them together.

Research is not merely the biggest job the department has—it is the foundation of all its other jobs. Research done in this department, coupled with new knowledge from institutions in all parts of the world, figures in everything the department undertakes. One may easily miss this fact in glancing over the list of the department's activities. In annual financial statements, for example, the duties are divided into six general classes: (1) research; (2) extension and information; (3) the eradication or control of plant and animal diseases and pests; (4) service activities, such as weather and crop reporting; (5) the administration of regulatory laws; and (6) road construction. This classification, though convenient for certain purposes, implies that research is only one among many equally important functions. Actually the research is primary. It is the keystone of the structure.

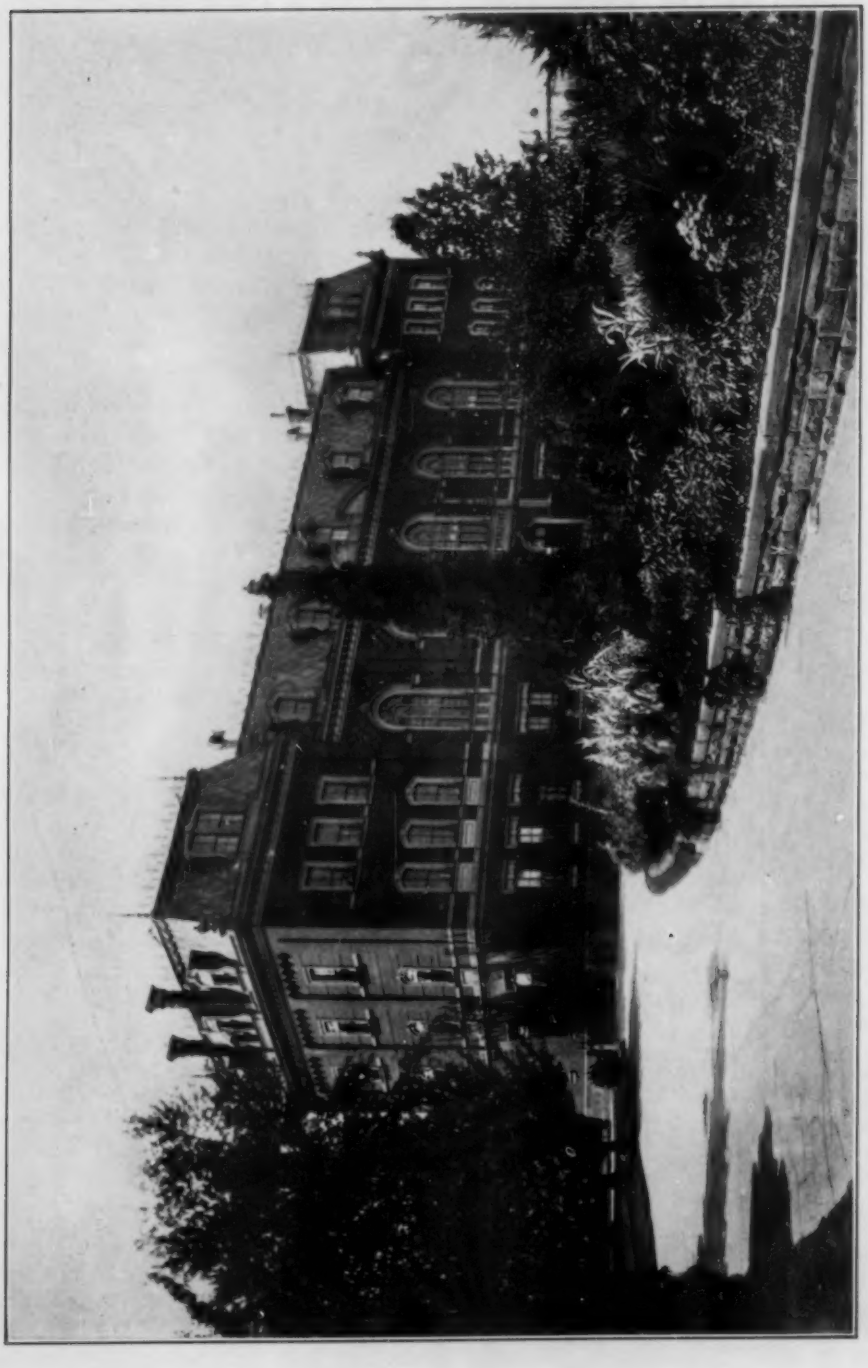
The foregoing classification of functions does not reflect an actual separation of tasks into water-tight compartments. It merely marks boundaries, not so much in the work itself, as in our way of conceiving the work. No sharp line can be drawn, for example, between research and extension. Research results have to be popularly presented before they can be usefully extended. Hence the extension work begins in the research laboratory, which furnishes the necessary educational material in a usable form. We classify weather and crop reporting as service activities, yet they are very largely research jobs. So is the eradication or control of animal and plant pests. Eradication campaigns would get nowhere without scientific knowledge.

Research bulks large in the administration of regulatory laws. The Food and Drug Law, for instance, forbids the sale of adulterated food and drugs, but it could not be enforced without scientific analyses and standards and research to perfect means of detecting adulteration. Expenditures by the department for road construction cover highway research as well. This research has produced revolutionary improvements in highway design.

In the succeeding articles of this series those in charge of research in the department will describe their projects and problems in some detail. I shall not attempt in any way to anticipate these writers. Something, however, should be said here about the origin and growth of federal research in agricultural science and about the resulting benefits.

It was recognized long ago that agricultural research is logically a public function. This is because few individuals or even corporations have the scientific motive, the public spirit, the money or the economic incentive to do it thoroughly. As a private enterprise it generally does not pay, since the benefits can not be monopolized but must be shared with the community. Publicly conducted, however, it pays large returns. In fact, it is one of the greatest sources of private and national wealth.

Early in our history Congress stated the research principle which has ever



OLD ADMINISTRATION BUILDING OF THE U. S. DEPARTMENT OF AGRICULTURE, BUILT IN 1868 AND TORN DOWN IN 1930.

since guided the department. In 1839 Congress appropriated $1,000 "for collecting and distributing seeds, prosecuting agricultural investigations, and procuring agricultural statistics," and when the organic act creating the United States Department of Agriculture was passed in 1862, Congress directed the institution "to acquire and diffuse useful information on subjects connected with agriculture in the most general and comprehensive sense." With this principle the country has never quarreled.

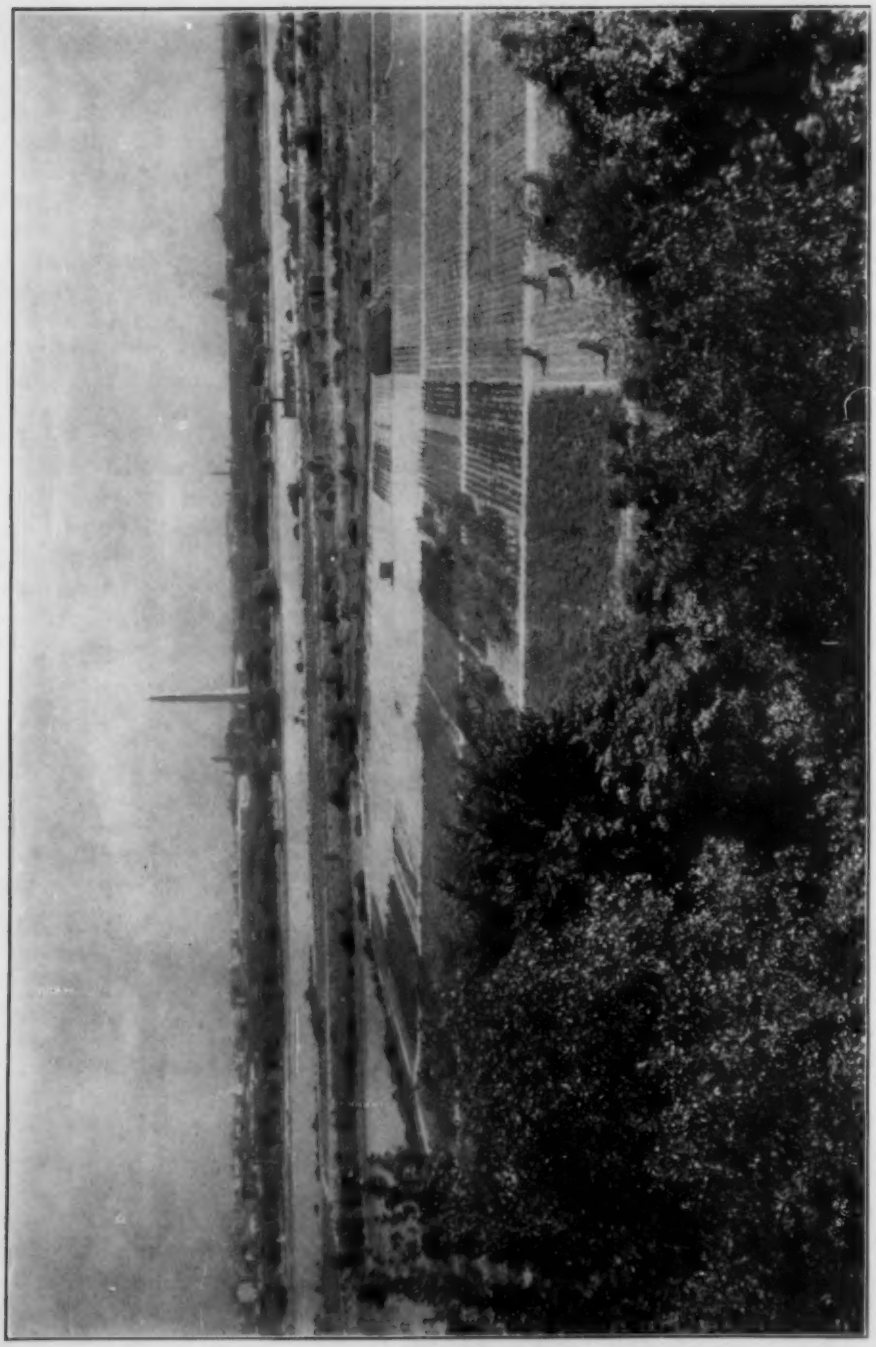
Occasionally, however, it has questioned the manner in which the principle has been applied. It is raising some questions on this point now. There is a tendency to judge the worth of federal agricultural research by the prevailing condition of agriculture. Since farmers are not making money it is charged that research does not serve their interests directly. One might as well say that an army should drop its weapons whenever the battle goes against it.

Agricultural science is more valuable to farmers now than at any other time. It reduces their cost of production, strengthens their competitive position in the world's markets, and lays a foundation for aggressive action to regain prosperity. The unthinking say research should be dropped in times of depression, and technical progress with it, because science and technique cause overproduction. This is a very dangerous fallacy. It does not necessarily follow when science shows how to grow two blades of grass where one grew before that two blades should be grown. If the market is poor it is better to grow one blade at half the previous cost. Broadly considered, agricultural science facilitates control of the volume as well as of the cost of production.

Federal research in agricultural science has of course grown enormously since the country first recognized it as a proper governmental activity, and the question whether the tree has been kept to the right size and shape and has branched in the right directions is entirely legitimate. I believe we may answer yes. The research system developed not from any preconceived plan, but gradually under the stimulus of keenly felt agricultural and national wants; hence it is not a mechanical creation but a living organism, evolving structurally and functionally in adaptation to its constantly changing environment. Thus in 1884 Congress appropriated money for the study and eradication of contagious pleuro-pneumonia, which had caused serious losses among live stock and prompted foreign countries to exclude animals from this country. The disease was investigated and stamped out and the export trade restored. This is a typical example of the way in which specific research projects in the department develop. Usually some situation demanding action gives the initial stimulus.

Concerning the test of results, I have no space to speak in detail. There is abundant evidence as to its substantial and many-sided character. Later articles in this series will furnish particulars. But I want to call attention to the fact that we can not measure the result in dollars and cents. It is too widely diffused and too complex for any such accounting. On each occasion when it has appeared in the United States the department has eradicated foot-and-mouth disease of cattle. What is the cash value of that achievement? We can merely guess how much damage the disease would have caused had it gained a foothold.

What is the value of hog-cholera control, of the increasing eradication of bovine tuberculosis, of the apparent extermination of the Mediterranean fruit-fly, of soil chemistry and soil surveys, of plant-disease prevention? It is literally incalculable, yet at the same time real and tangible.



ARLINGTON EXPERIMENT FARM.

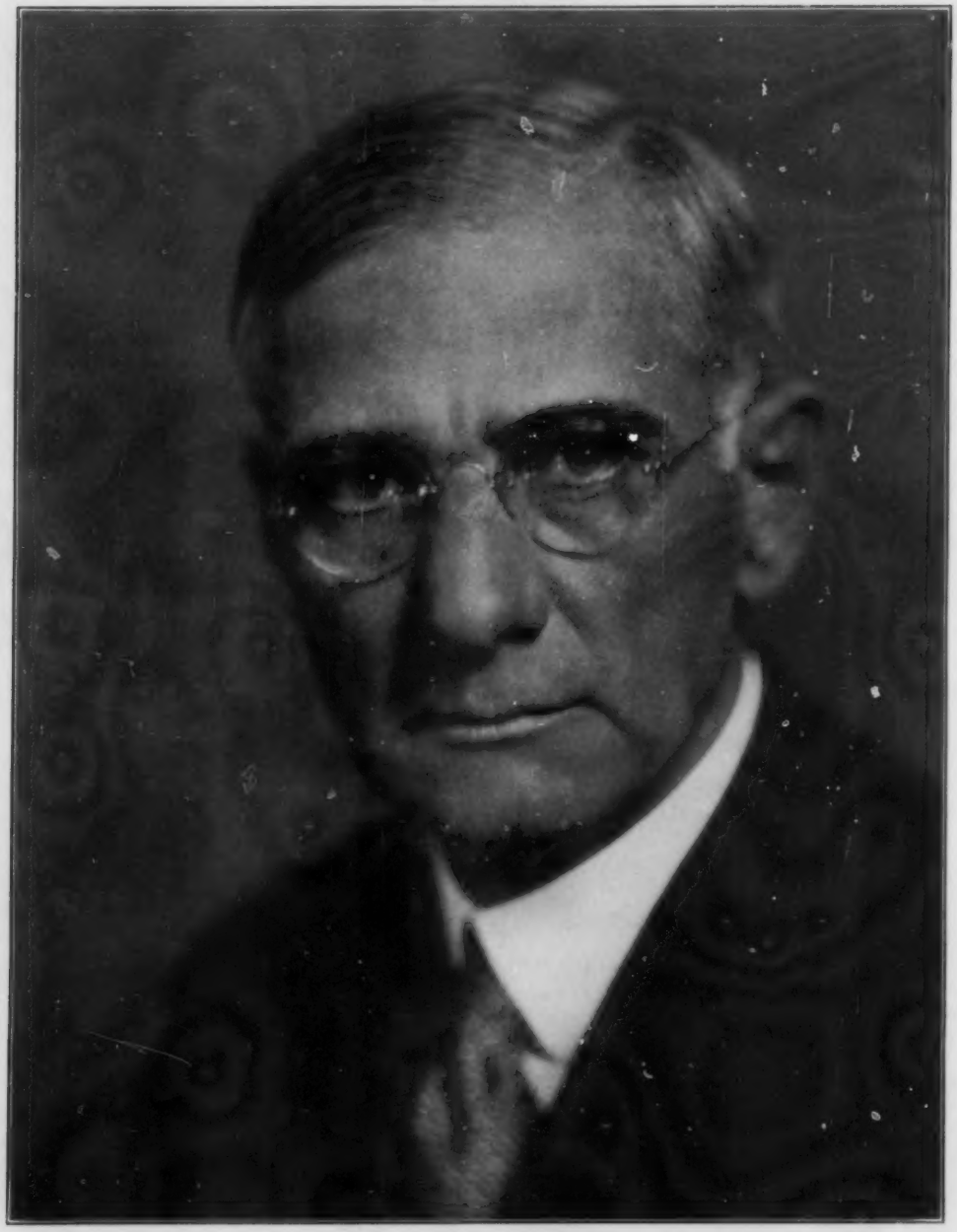
The worth of federal research in agricultural science can not be measured in profits or even in exact degrees of agricultural advancement. Its benefits do not go exclusively to any group but become diffused throughout the community. Agricultural science developed in the department enters the general stream of science to stimulate and nourish the whole culture of mankind.

Let me give just two examples of fruitful research in the department:

Splenetic fever in cattle, formerly known as Texas fever, devastated the herds of Southern stockmen for decades. It gave foreign countries a reason for excluding American cattle and cattle products. It was the greatest obstacle to the Southern live-stock industry. Research in the Bureau of Animal Industry from 1888 to 1893 resulted in an epoch-making discovery. It demonstrated that a microorganism found in the blood of cattle affected with Texas fever was the actual cause of the disease and that the cattle tick is the means whereby the disease is transmitted. This was the first demonstration that a microbial disease can be transmitted exclusively through the agency of an intermediate host or carrier. Tick eradication work followed, with gradual suppression of the disease. But that result, though immensely important, was a mere detail compared with the vast significance of the discovery, which ranks among the great achievements of medical science. It led to the knowledge that such diseases as yellow fever, malaria, typhus fever, African sleeping sickness, Rocky Mountain fever and other maladies are carried through an intermediate host. It made possible the control of yellow fever in the Panama Canal Zone.

Sometimes research in the department anticipates the way to combat a plant disease. A brilliant modern example is the restoration of the sugar-cane industry in Louisiana, which not many years ago was threatened with extinction by mosaic disease. It had been demonstrated many years previously that resistance to disease and also to climatic conditions is a genetic character that may be bred into or out of plants. Mosaic disease was discovered in 1919 in a small part of the sugar-cane area in eastern Louisiana. It spread rapidly through that state and into other sugar-cane growing states. Great areas of cane lands passed out of cultivation; sugar mills remained idle; and the sugar-cane industry faced collapse. Mosaic disease can not yet be cured because its nature is unknown. Accordingly the department undertook to develop resistant varieties. It imported strains known to be tolerant of the mosaic disease. These varieties, propagated from cuttings, were planted in 1928 on 135,000 acres in Louisiana. In 1929 the acreage planted to sugar-cane compared favorably with the acreage grown before the appearance of the mosaic disease.

Research in the department, though not carried on exclusively for the benefit of farmers, naturally interests farmers more than any other group. It discovers short cuts to the knowledge required in adapting agriculture to changing conditions. In a stable situation experience alone would eventually perfect an adequate technique. But no situation is stable. In a rapidly changing situation, like that with which farmers have now to deal, blind groping is too slow and costly a method of initiating necessary modifications in farm practices. Research, through observation and experiment under controlled conditions, establishes principles which lessen the risk of experimentation. Since experimentation is obligatory, whatever helps to give it purpose and direction reduces farm expenses as definitely and tangibly as a new machine or a higher yielding crop. In other words, research is the farmer's best guide to the avoidance of useless struggles.



ARTHUR M. HYDE
SECRETARY OF AGRICULTURE.

THE DEVELOPMENT OF AGRICULTURAL RESEARCH AND EDUCATION UNDER THE FEDERAL GOVERNMENT

By Dr. A. F. WOODS

DIRECTOR OF SCIENTIFIC WORK, UNITED STATES DEPARTMENT OF AGRICULTURE

ONE of the most valuable fruits of the Renaissance was a realization that education must deal more with reality and the application of knowledge to the problems of every-day life. Many schools were established with this in view. Modern science had its birth in this idea of studying nature by observation and experiment. From such studies gradually grew the sciences of physics, chemistry, biology and geology, and their applications to every-day life. It soon became apparent to all that *real knowledge* was useful.

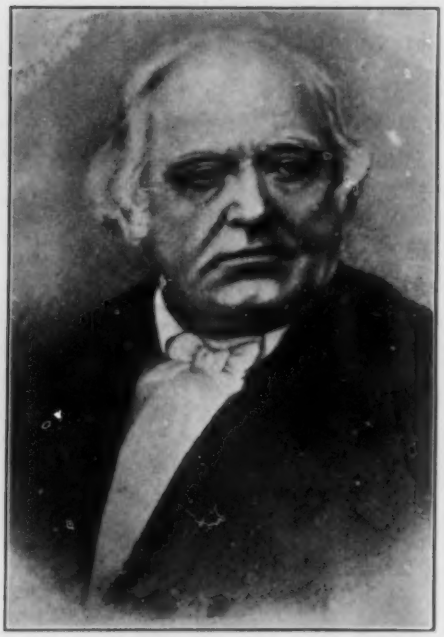
As accurate knowledge increased and we developed increasing control of natural forces and things, there was an increasing desire on the part of people generally for the benefits that might flow from such knowledge. To trace the history of this great development would be impossible in this paper, but we should recognize that out of these beginnings in the sixteenth and seventeenth centuries grew the science of to-day and our own appreciation of the economic and social value of science and research. Its importance was realized by many of the leading spirits in our own early history, especially by Franklin, Jefferson and Washington.

In his first message to Congress in 1790 Washington suggested that science and literature might be promoted by the institution of a national university, and in 1796 he definitely recommended the establishment of such an institution.

In his last message to Congress, on December 7, 1796, Washington said: "In proportion as nations advance in population the cultivation of the soil becomes more and more an object of public patronage." Washington recommended that appropriate steps be taken by Congress to promote agriculture in the United States. Congress gave much consideration to ways in which this might be done. Agricultural societies were organized and devoted much thought to the subject. A full realization of Washington's idea was not consummated until long after his death. The great agricultural and industrial expansion growing out of the settlement of the West, the decline of agriculture in the older settled portions of the East, the need for better crop plants and domestic animals, the need for new crops better adapted to the changing requirements, led the United States Agricultural Society, which was established to carry out Washington's idea, to adopt a resolution at its meeting on February 2, 1853, favoring a department of agriculture, with a cabinet officer at its head. The society was very active in presenting this idea to Congress and to the public.

Such plans received strong support from leaders of thought, educators, state legislatures and members of Congress. They finally crystallized into the act establishing the United States Department of Agriculture, passed by Congress in 1862 and signed by President Lincoln on May 15 of that year, and the Morrill Act, signed by Lincoln on July 2 following, establishing the land-grant colleges.

The organic act establishing the Department of Agriculture is very broad:

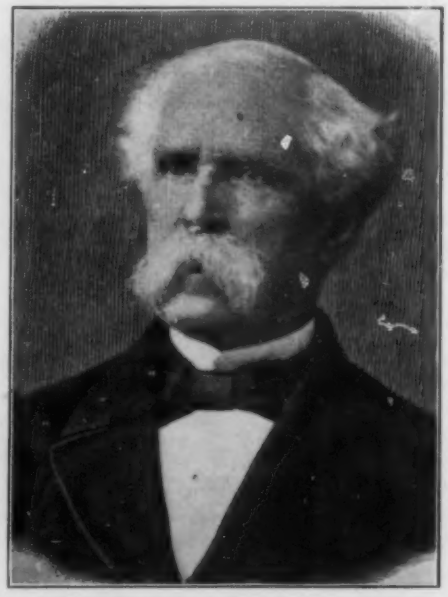


ISAAC NEWTON
COMMISSIONER OF AGRICULTURE, 1862–1867.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there is hereby established at the seat of Government of the United States a Department of Agriculture, the general designs and duties of which shall be to acquire and diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word, and to procure, propagate, and distribute among the people new and valuable seeds and plants.

Agricultural work previously done through the Patent Office was transferred to the new department, and the portion of the mall now occupied by the department was transferred to it. Isaac Newton, the first agricultural commissioner, personally supervised the laying out of the tract, as an experimental farm. Commissioner Newton suffered a sunstroke while supervising some work on this farm in July, 1866, and died from the effects about a year later. He appointed William Saunders, who later became famous as the landscape designer of Gettysburg Cemetery, as superintendent of the propagating garden. This was the first step in what is now the department's Bureau of Plant Industry. He also appointed C. M. Wetherill department chemist. This appointment led in time to the Bureau of Chemistry. In 1863 Lewis Bollman was made statistician. His work grew into the statistical service, now a part of the Bureau of Agricultural Economics. Townsend Glover was appointed entomologist and was thus the father of the Bureau of Entomology. Newton took over the publication of meteorological data gathered by the Smithsonian Institution. This was transferred to the Signal Service of the Army by Congressional act in 1872, and transferred again to the Department of Agriculture by Congress on October 1, 1890.

The first building for the department was erected during the administration of Commissioner Capron, 1867–71. He was especially commended for keeping the



HORACE CAPRON
COMMISSIONER OF AGRICULTURE, 1867–1871.

FREDERICK WATTS
COMMISSIONER OF AGRICULTURE, 1871–1877.

cost within the amount appropriated. About this time Texas fever of cattle became a serious menace, and the Division of Veterinary Surgery was established to study this and other diseases of live stock.

During this period also, at the suggestion of Professor Joseph Henry, of the Smithsonian Institution, a Division of Botany was organized for the special purpose of making a scientific study of economic plants. Commissioner Capron resigned in 1871 to become agricultural adviser for the Government of Japan.

The next commissioner, Frederic Watts, found in successful operation the Division of Chemistry, Gardens and Grounds, Entomology, Statistics and Botany. He organized a Division of Microscopy, which gave special attention to mushroom cultivation, cranberry rot, mildew of grapes, peach yellows and black knot of plums.

Succeeding commissioners, Le Duc, Loring and Colman, perfected the work already established. The Division of Forestry was organized during this period, thus laying the groundwork for what is now the Forest Service.

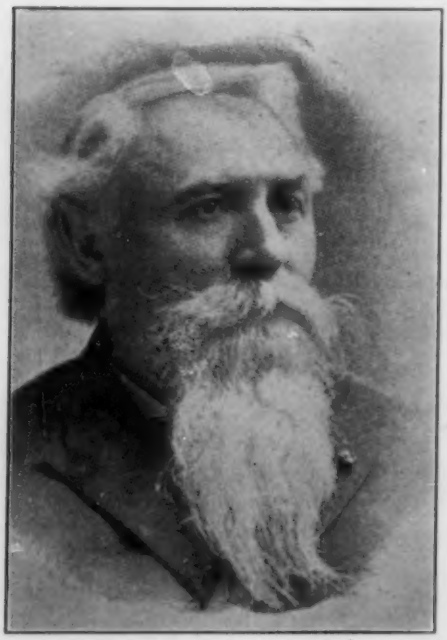
The outstanding accomplishment during the administration of Commissioner Loring was the introduction and distribution of the Bahia seedless orange, now known as the Washington Navel, yielding about 35 million dollars a year to California. He reorganized and enlarged the Division of Statistics into an official crop-reporting agency, and placed an agent with the Consul General in London for collection of information on the foreign demand for agricultural products.

During the latter part of Commissioner Loring's administration the law creating the Bureau of Animal Industry was passed by Congress and approved on May 29, 1884. This was in response to a growing realization of the losses caused by animal diseases, such as pleuro-pneumonia, and the dangers of

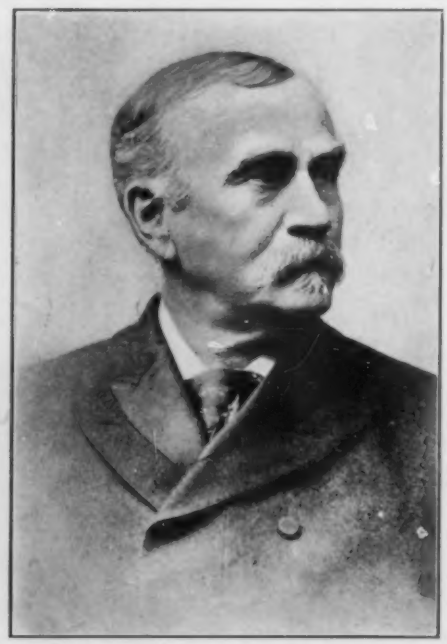
WILLIAM G. LE DUC
COMMISSIONER OF AGRICULTURE, 1877–1881.

GEORGE B. LORING
COMMISSIONER OF AGRICULTURE, 1881–1885.

NORMAN J. COLMAN
COMMISSIONER AND SECRETARY OF AGRICULTURE, 1885–1889.



JEREMIAH M. RUSK
SECRETARY OF AGRICULTURE, 1889–1893.



J. STERLING MORTON
SECRETARY OF AGRICULTURE, 1893–1897.

spread of this and other infectious and communicable diseases of live stock. Broad powers of study and control were given, including quarantine and eradication. Almost every phase of animal industry as now organized was foreshadowed in this bill.

During Commissioner Colman's administration, 1885–89, the Hatch Act, establishing the agricultural experiment stations, was passed by Congress (1887). These stations were to be supervised in a general way by the federal Department of Agriculture. The Office of Experiment Stations was organized for that purpose.

During this period the rapidly expanding horticultural interests of the country, with increasing losses from causes which were obscure, led to greater emphasis on these problems. A Division of Pomology was organized to bring together scattered information on fruits. A Section of Mycology was organized in the Division of Botany to give special attention to fruit diseases, particularly those of the grape and peach. A Division of Ornithology and Mammalogy was established, especially to study the damage done to crops and fruits by birds. This latter grew into a more extended study of the beneficial and harmful species of wild life in general and developed into the Bureau of Biological Survey.

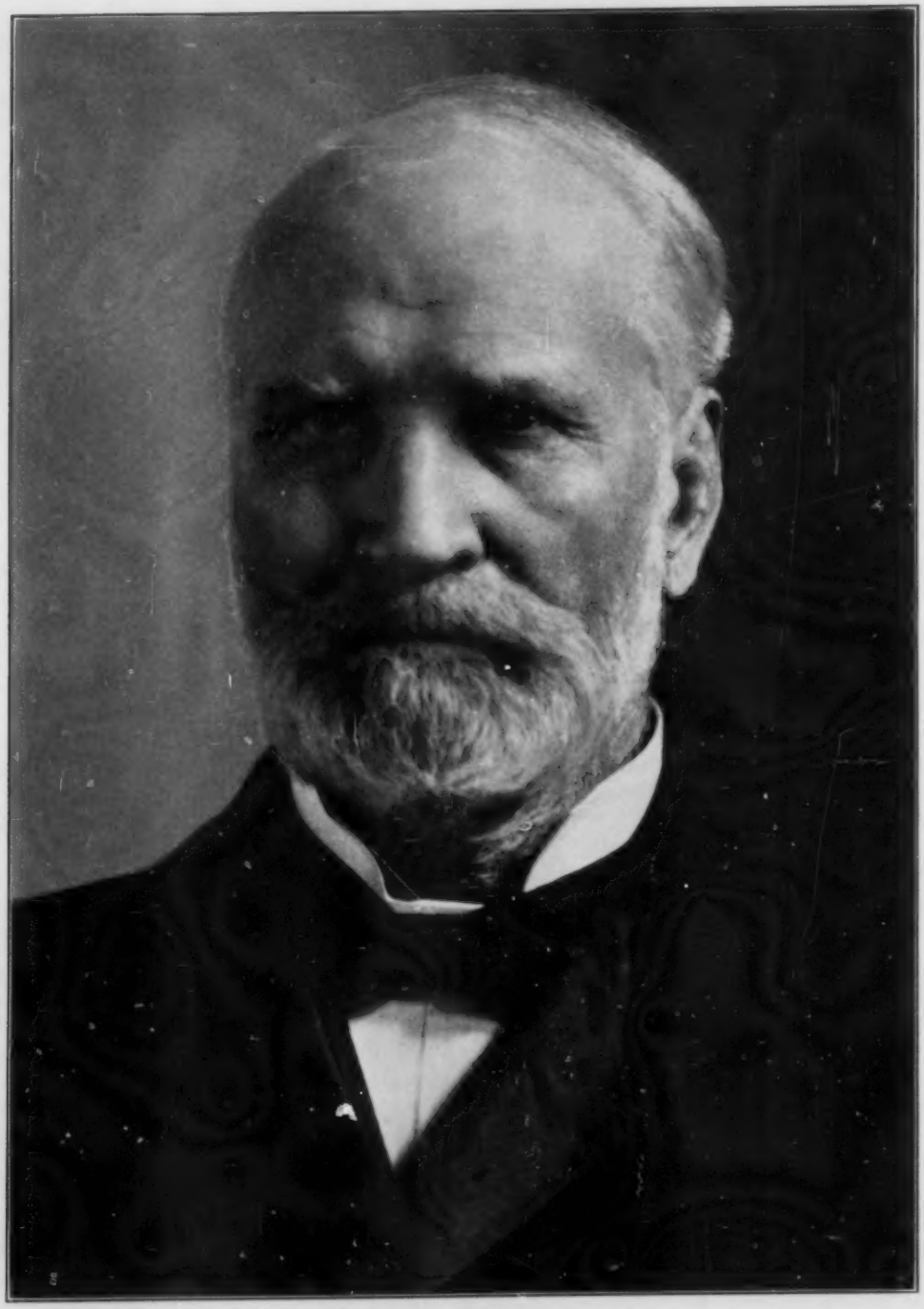
By act of Congress approved by President Cleveland on February 9, 1889, the Department of Agriculture became an executive department under the control of a secretary, appointed by the President, with the advice and consent of the Senate. The secretary therefore became a member of the President's cabinet. Commissioner Colman was appointed secretary, retaining the position to the end of the administration, a little less than a month.

Jeremiah Rusk was appointed secretary during the administration of President Harrison. He inaugurated the *Farmers' Bulletin* series and organized the editorial and publishing work of the department into a Division of Records and Editing, which has passed through several transformations and is now the Office of Information, handling all publications and information activities for the department as a whole.

During this period meat inspection for export and interstate commerce was inaugurated as a result of growing complaints against exportation of diseased meat. Progress was made in the study and control of Texas fever. The discovery was made that the parasite causing the fever was carried and conveyed by the bite of an infected tick, thus opening up an entirely new field of disease transmission.

The Weather Bureau was transferred from the Signal Service to the Department of Agriculture under the Cleveland administration. Hon. J. Sterling Morton, of Arbor-day fame, became secretary. He reorganized and enlarged the forestry work, organized the Division of Agrostology for the study of forage plants; established the Division of Soils and Soil Survey; established the Office of Road Inquiry, now the Bureau of Public Roads; organized a Dairy Division in the Bureau of Animal Industry; consolidated the Division of Microscopy with the Division of Mycology and Plant Pathology and encouraged the extension of Civil Service regulations through the department. He attempted to abolish Congressional free-seed distribution. discontinued the Annual Reports, and established the Yearbook series.

James Wilson, of Iowa, became secretary in 1897. His administration (1897–1913) was notable for reorganization and consolidation of related fields of work. The divisions dealing with plants were combined into a Bureau of Plant Industry. Farm-management work was



JAMES WILSON
SECRETARY OF AGRICULTURE, 1897–1913.

organized in the bureau, and special studies of marketing problems inaugurated. Regional studies of key-crop industries were begun to find what was most needed to improve the agricultural industries and to put them on a more permanent basis. Agricultural explorations were undertaken to find improved varieties of crop plants for direct use and for crop-breeding purposes. Many valuable introductions were made, among these the durum wheats, now the basis of the American macaroni industry; the hardy Turkey wheats from Russia, which have revolutionized wheat-growing in the Great Plains; hardy alfalfa and a host of other legumes and forage plants; many new varieties of soy-beans; the date palm and the Chinese date or jujube; Smyrna figs; Oriental persimmon. Much attention was given to plant breeding, especially to the production of disease-resistant varieties.

The work of the Division of Soils was expanded into a bureau, with special reference to the factors determining fertility. Soil surveys were speeded up, and special attention was given to the adaptation of the soil types to special crops. The work of the Division of Forestry was enlarged, especially by transfer of the forest reserves to the department. Congress also authorized the President to set apart additional reserves. A comprehensive plan of forest conservation was developed. The division became the Bureau of Forestry, or the Forest Service, as it is now known. The Division of Chemistry gave special attention to problems of food control and laid the groundwork of the Pure Food Law, which for many years was administered by this division, which became the Bureau of Chemistry.

The Division of Ornithology and Mammalogy had developed much valuable information regarding useful and harmful birds and mammals. Several acts of Congress had placed on the department the responsibility of regulating the importation and killing of certain species. Bird refuges and game preserves were established. The work was reorganized as the Bureau of Biological Survey.

The work of the Division of Entomology had developed, especially on the control of cotton boll weevil, pink boll worm and similar pests. The division was reorganized as a bureau. In 1903 the building of the east and west wings of the new building for the department were authorized, leaving a central unit to be provided. This latter has recently been completed and occupied.

The outstanding feature of the administration of Secretary Houston (1913–1919) was the consolidation of the economic, statistical and marketing work into a Bureau of Markets, now the Bureau of Agricultural Economics, which took out of the other bureaus this type of work and unified it.

Secretary Wallace's administration (1921–24) was characterized by a special examination of the status and needs of the various branches of agricultural industry, especially from the economic aspects. He further grouped the main functions of the department for general administration purposes into scientific work, regulatory work, extension, information and business administration, with a director, ranking as an assistant secretary, in charge of each. The purpose of this was to bring about better cooperation and correlation and more uniform policies.

The next important reorganization step was the separation of regulatory work from research, taken during Secretary Jardine's administration (1925–29). The food, drug and insecticide control was taken out of the Bureau of Chemistry and set up as a special service dealing only with the regulatory features of the work, the research remaining in the research bureaus. Plant

DAVID F. HOUSTON
SECRETARY OF AGRICULTURE, 1913–1919.

quarantine and control functions were removed from the Bureau of Plant Industry and the Bureau of Entomology and organized as a service unit. The regulatory and research work have been much more effective since this separation. Close cooperation is maintained so that any research needed by the regulatory units can be promptly taken care of.

The Bureau of Chemistry, Bureau of Soils and the Fixed Nitrogen Laboratory, having much in common, were consolidated into a single Bureau of Chemistry and Soils, and the soil fertility work of the Bureau of Plant Industry transferred to the new bureau.

The present administration under Secretary Hyde is emphasizing a clearer distinction between Federal and State responsibility, elimination of duplication within and outside the department, better correlation of state and federal work. All work is rapidly being reduced to a definite project basis and the work of the department restricted to the larger regional problems and those requiring the cooperation of the states and federal government. Local matters are being turned back to the states.

In 1887 the Hatch Act was passed, establishing the experiment stations in connection with the land-grant colleges and providing for close relations with the federal Department of Agriculture. This was later supplemented by the Adams and Purnell acts. All these acts have been supplemented from time to time with legislation enlarging the scope, increasing the funds and providing for closer correlation of work. Under the stimulus of these acts there has been built up a group of closely affiliated educational and research agencies, federal and state, that are devoting their energies to improving agriculture and

EDWIN T. MEREDITH
SECRETARY OF AGRICULTURE, 1919–1921.

HENRY C. WALLACE
SECRETARY OF AGRICULTURE, 1921–1924.

HOWARD M. GORE
SECRETARY OF AGRICULTURE, 1924–1925.

country life and related industries, and rendering service in many ways to the nation as a whole.

It was Bacon who coined the phrase "Knowledge is power." Scientific research supplies the facts that are the basis of knowledge. It is *industry* that has brought knowledge into the everyday realization of humanity by making

WILLIAM M. JARDINE
SECRETARY OF AGRICULTURE, 1925–1929.

life easier, safer, happier and more satisfying through the development of mechanisms that apply human intelligence automatically to a very large degree and utilize the unseen energies of the universe for the good of man.

In this group I also include that great group of industries known under the general designation of agriculture. Agriculture and the mechanic arts develop hand in hand. Food and raw materials grown on our cultivated lands and in our forests and transformed by animals and by manufacture in a thou-

A MISSOURI FARM HOME, HARRISONVILLE, MISSOURI.

sand ways *are fundamental to all the rest.* It was and is therefore the concern of all our people that this reservoir of power shall not be depleted but remain for all time as the source from which life-sustaining power may be always available.

Man power, food and raiment, materials for home and for industry are the elementary products. Every civilization that has neglected this source of renewing its energy has decayed. The founders of this republic determined from the beginning that it should not suffer the fate of other civilizations that forgot agriculture and perished.

The Department of Agriculture and the land-grant colleges, the experiment stations and the extension service are agencies that find the facts in respect to climates, soils, crops, animals, foods and products of farm and forest, and see that these facts are made available to the people. The work includes production, conservation and distribution and use for the welfare of all concerned.

On this foundation commerce and industry rest as on a rock. If the foundation is secure all is well, but if it is insecure the superstructure falls. No thinking person to-day disputes the wisdom of that policy established by our fathers of doing everything possible to insure the security and permanency of agriculture as the foundation of national security.

Perhaps nowhere in our lives is the educative value of responsibility and independent effort more evident than on the farm. The farm boy and girl are intelligent and alert about many things not found in text-books. They meet and control many difficult situations—problems of weather, soils, pests, competition, isolation. The farmer has thus come to depend largely upon his own efforts and judgment. This has bred up a race of

men and women noted for their independence.

It is the farm-trained boys and girls that have developed into the great leaders in industry, commerce, education, the ministry and other professions. This contribution of real men and women to the life of the nation is one of our greatest assets. Dr. Liberty Hyde Bailey has forcefully expressed this in the "Farmer's Challenge" in his book of poems entitled "Wind and Weather," published by the Macmillan Company:

Blow ye winds and lay on ye storms
And come ye pests in rabble swarms
And fall ye blights in legion forms—
I am here: I surrender not
Nor yield my place one piece or jot—
For these are my lands
And these are my hands
And I am bone of the folk that relentlessly stands.

The blood of old plowmen runs hard in my arm
Of axemen and yeomen and battlemen all
Who fought and who flinched not by marsh or wall
Who met the bold day and chased ev'ry alarm;
My fatherkind sleep, but I hear the old call
And fight the hot battle by forge and by farm—
For these are my lands
And these are my hands
And I am bone of the folk that relentlessly stands.

Farming is a life as well as a business and we must not lose its values by too great isolation and lack of organization on the one hand or too great industrialization on the other. Either extreme would be bad for the farmers as well as for the nation.

The rural economic and social unit is the farm family. There are about six million farm families, constituting about one fourth of our population. The problem before us is how we can help the rural population to help themselves; to have comfortable homes, paying farms, good roads, schools and churches; to maintain their individual independence and yet act together for their common welfare.

Here arise new difficulties that are partly local and partly state and national in their aspects.

We desire to solve the problem without too greatly reducing our rural population in relation to urban. We desire

A MODERN FARMSTEAD IN PENNSYLVANIA.

A TYPICAL FARMSTEAD OF AVERAGE SIZE.

to maintain on the land our most virile people—at least there should be no reduction in quality. To accomplish this there must be as good opportunity for the country boy and girl to get the worth-while things in life as there is for the city boy and girl. This means good homes, good farms, good schools and cooperation.

The starting point in agriculture is soil. If the soil is good and adapted to the crops grown we have the foundation of good agriculture. If the soil is not good or not adapted to crops grown we have the beginning of the failure.

We have no scientific land policy in America. We have cut down the forest and plowed up the prairie and put the land into corn, wheat and cotton, cattle, pigs and poultry, with no regard to soil or market requirements or competing areas. We have built up one community only to have it pushed to the verge of bankruptcy by developing new areas. Millions of acres of land adapted only for forests or range have been sold for general farming purposes. There is no present need for these lands in general crop production, but there is a real need for them in forest or pasture, in which they will give good economic return in the production of wood and other needed forest products or in the production of grass.

We are using our timber resources four times as fast as they are being reproduced. Unwise removal of forest and grass cover is causing rapid run-off of rainfall, causing erosion and land destruction, the filling of stream beds, with resulting floods, etc. By so doing we are opening Pandora's Box for our children, if not for ourselves, and wasting billions of dollars of wealth each year.

The need for a sound, wise government policy, backed by public opinion, is essential to our present and future welfare.

The federal Department of Agriculture and the land-grant colleges have long stood for such a policy and are doing everything in their power to bring it about. They have been making soil surveys and soil studies for many years. They have done much towards pointing out areas and soil types that should be devoted to state and national forests and

those adapted to staple crops. They have aided in formulating legislation to protect and promote the policy, but progress is very slow, due to lack of public understanding of the problems involved.

A sound land-utilization policy is the first step in the solution of our so-called agricultural problem. It would bring no more non-agricultural land into crop production. It would gradually bring back into forest or pasture land that is already unprofitably farmed and thus put it on a paying basis. This would tend to stabilize crop production and reduce surpluses. It would tend to stabilize the business of wood production and business based on forest products generally. It would help to prevent erosion, regulate stream flow, conserve water resources, including fish and game, and, last but not least, *water power*. The direct and indirect benefits of such a policy will be apparent to any one who gives the matter careful thought.

Coming back to our good agricultural land, we find that, too, must be protected on steeper slopes, at least from erosion, by proper terracing and planting. We lose by erosion 20 times as much fertility in large areas of fertile soil as is taken out by crops, and worst of all we gradually lose the soil itself. This can usually be prevented by proper cultural practice.

We know, too, that fertility is itself a complex matter, involving microorganisms, bacteria, protozoa, worms, algae, fungi, and numerous other kinds of living organisms, some harmful, some helpful. These have their effects on the

FARMING ON SUCH A STEEP ROCKY SLOPE,

WHICH IS UNTILLABLE AND NOT PASTURABLE FROM THE STANDPOINT OF ECONOMY, SHOULD NOT BE UNDERTAKEN.

TERRACES TEN YEARS OLD IN ARKANSAS HAVE CONSERVED SOIL.

inorganic materials forming the body of the soil, and the nature of those inorganic materials and their solutions and content of air and water all are involved. If conditions are right fertility may be maintained and improved. If they are wrong fertility may be lost.

Crops constantly take out of the soil materials that must be replaced. Here comes in the problem of fertilizers and their use.

These problems are too complex for the farmer to work out for himself, so there has been a wise provision by the Federal Government and the states to provide for such study through the experiment stations, the land-grant colleges and the research bureaus of the U. S. Department of Agriculture. It would be impossible for individual farmers or groups of farmers to undertake such work except in highly specialized industries.

Next to the soil the most important factor in successful agriculture is the plant, the great converter or transformer of sunlight and soil into forms available as food for animals. If green plants should perish from the earth all animal life would soon die. If the farmers should cease their labors for a few months civilization would quickly decay, cities would disappear and men would become beasts of the forest. So agricultural plants and the men who grow them are important factors, worthy of the most careful thought of all people.

One plant differs from another plant in its ability to live and work under given conditions, adaptation to soils, to climates, resistance to diseases and insects, ability to produce the products desired, etc. Plants that are not adapted are inefficient and result in failure or loss to those growing them.

Here again the great research agencies of the Department of Agriculture and the state experiment stations are doing

much to help the farmer get crop plants that are best adapted and most efficient for the conditions he has to meet. Agricultural explorers search the world for needed material for direct use or for breeding purposes. Improved varieties of cotton and corn, grasses and clovers, wheat and other small grains, have more than doubled the average yield since this work began. *Quality* has been greatly increased. Adjustments to climate, soil and market needs have been and are being made. Resistance to disease and insect pests have been worked out, and much work is in progress. In this field of disease and pest control great advances are possible, as losses that might be prevented are still enormous, aggregating several billion dollars a year. Manifestly here again the individual must be aided by the government and the state in the interest of public welfare.

What has been said about plants is true also of farm animals. One cow differs from another cow in meat and milk and butter-fat producing power. Some cows do not pay their board bill; others on the same feed yield a good profit. The same is true of poultry and hogs.

Then there is a host of insect pests and diseases to combat. All these require careful study in order to control them. Here again the federal department and the state experiment stations help the farmer in the interest of public welfare.

Soils and crops and animals are not all. There is the question of economics of production; the combinations of crops and animals; the most economic use of machinery, labor and capital; the problem of markets; home and foreign marketing methods; cooperation; market information; standardization; grades; finance; transportation; etc., etc. This involves world study and statistics on a large scale. It is, for agriculture at least, manifestly a federal and state function.

The Bureau of Agricultural Economics of the federal Department of Agriculture makes these studies for agriculture, cooperating in many phases of the work with the Department of Commerce, which makes similar studies for commerce and industry. Sound business

PINE TREES CHECKED EROSION IN THIS GEORGIA PASTURE.

SOUTHERN COUNTY AGENT HOLDS A TERRACING DEMONSTRATION TO SHOW HOW TO PREVENT SOIL EROSION.

methods applied to agriculture with effective organization and cooperation will add greatly to its stability and attractiveness as well as efficiency.

One of the most potent forces influencing production is weather. Favorable or unfavorable weather has more to do with volume and quality of production than any other group of factors. Except in very intensive agriculture under glass, weather can not be controlled except within narrow limits. On a limited scale fruit can be protected from frost by smudging. Electric light can in a small measure intensify light when needed. Drainage can overcome the effects of too great rainfall and irrigation provide for a lack of it. But all these methods are applicable only on a small scale in intensive industries.

Usually and generally the farmer must have crops adapted to the range of temperature and moisture conditions. To do this intelligently and safely he must have accurate data as to early and late frost, maximum and minimum temperatures, rainfall, wind velocity and sunshine and cloudy weather or light intensity.

Thus the Weather Bureau of the United States Department of Agriculture provides not only for the farmer but for commerce and industry, shipping, air service, army and navy, and the people generally. It has come to be so much a part of our life that we hardly realize that it takes a great mechanism operating night and day every day in the year over a large part of the world to do the job.

There is the engineering side of agriculture—farm machinery, construction of buildings, the use of power, terracing, drainage, irrigation, road construction, etc. To furnish information in these fields we have the Bureau of Agricul-

tural Engineering of the Department of Agriculture. Much help is also available through the engineering departments of the land-grant colleges. The advance in machinery has greatly reduced labor costs and increased output per worker on the farms as well as in industry. It has done away with drudgery on the farm and in the farm home to a considerable extent.

The great national cooperation in road construction is carried on under the Bureau of Public Roads.

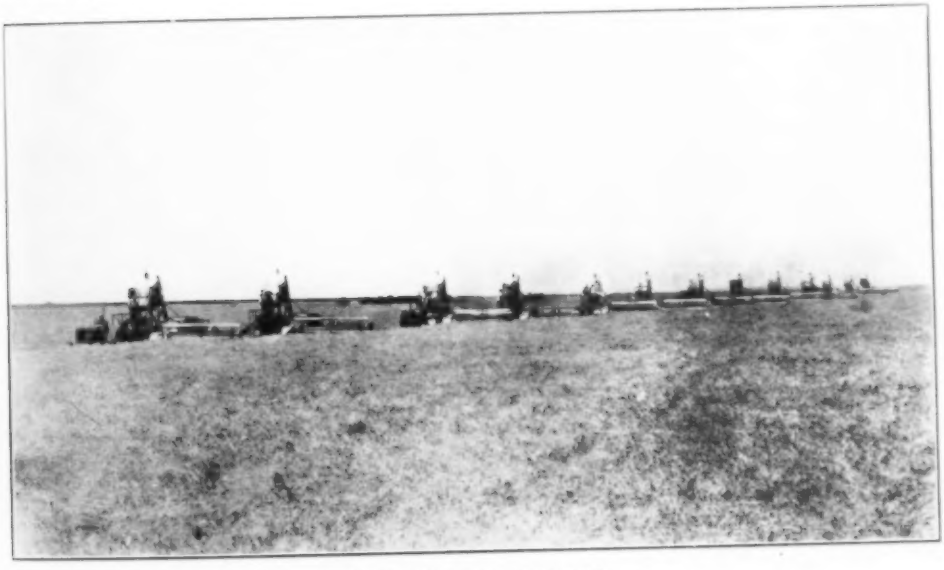
So much for the business side of agriculture. Let us look for a moment on the social side centered in the home. Here great changes are rapidly coming about as a result of the new developments in home economics in the colleges and the Bureau of Home Economics of the Department of Agriculture. Home planning to reduce labor, improve sanitation and comfort and preserve beauty are now subjects of interest to farm women. The same is true relative to clothing.

Food values have taken on a new interest since the discovery of vitamins and their importance to health, in which the experiment stations and the department have taken a very large part. New and improved methods of cooking and preserving and serving foods of various kinds are being worked out. Extensive studies are being made of the social factors in rural life and methods of improving them. This applies especially to the school and church.

Much attention is being given also to recreation and public entertainment and all the other factors that create interest and satisfaction in life.

The Purnell Act, recently passed by Congress, provides for extending the research functions of the agricultural experiment stations of the land-grant colleges to include home economics and rural sociology. Much valuable work has been started in this field, much of it is in cooperation with the Federal Department of Agriculture.

Rural free delivery, the telephone and



A MECHANIZED FARM

THIRTEEN COMBINES HARVESTING ON A 6,500 ACRE WHEAT RANCH IN ADRIAN, TEXAS.

A CLASSIFICATION OF THE TOTAL EXPENDITURES CHARGED TO THE DEPARTMENT OF AGRICULTURE FOR THE FISCAL YEAR 1931.

the radio, improved roads and the automobile have so reduced distance and time that rural isolation is largely a thing of the past. It is not at all uncommon for a whole family to drive a hundred miles to a conference.

Yet the large number of units to deal with and the complexity of the problems involved and the regional and local adjustments constantly required makes it necessary to have a special form of educational work known as Agricultural and Home Economic Extension. This was provided for under the Federal Smith-Lever Act, which became a law in 1914. The land-grant college in each state, cooperating with the federal Department of Agriculture, provides farm and home demonstration agents in most of the agricultural counties of the United States. The agents live and work in each community and keep the farmer in touch with specialists in the various fields in which he is interested. This is proving to be one of the most effective extensions of the land-grant college plan that has ever been undertaken. Through its development we may hope to maintain that is necessary for the most efficient basis and still secure that cooperation that is necessary for the most efficient business operation and satisfactory living.

The social values of rural life at its best may thus be conserved along with improved economic conditions. This is more in accord with our American democratic ideals than the more complete industrialization on the one hand or peasantry on the other.

To review briefly, therefore, the federal Department of Agriculture is an arm of the government established especially to promote agriculture by research, education, extension, and special types of service. It cooperates in this work especially with the land-grant colleges of the states, including the experiment stations and extension services. These agencies, working in harmony, are developing an agricultural policy for the United States in cooperation with the rural people.

One other phase of the work of the federal Department of Agriculture should be mentioned. *viz.*, the regulatory. Enforcement of the Pure Food and Drugs Act has very close relations to producers, manufacturers, dispensers and users of food products and drugs passing in interstate commerce. Purity and honest labeling are the main purposes of the act. It has had much to do in bringing about these desired objectives.

The meat inspection law, in force as to all meat passing in interstate commerce, with federal inspectors in all markets doing an interstate business, protects the meat users of the nation and the world so far as they use meats produced in the United States.

The department enforces the Migratory-bird Treaty Act, the Grain Standards Act, Federal Horticultural Inspection and Quarantine, Warehouse Act and various other acts involving agricultural products or protection of agriculture or the consumers of agricultural products.

Eradication and control work involves such projects as tick eradication, tuberculosis eradication, eradication of foot and mouth disease, hog cholera control and control of other epidemic diseases of animals, blister-rust control of white pine, barberry eradication for the control of wheat rust, eradication of citrus canker, etc. In the insect field we have the control of the corn borer and other moths, Japanese beetle, Mexican fruit-fly, eradication of pink boll worm of cotton, control of the cotton boll weevil, etc.

The service work includes such activities as the administration and protection of the national forests, the weather srvice, crop and live-stock estimating, market news service, shipping point and terminal market inspection on perishable farm products, and other work of like character for the benefit of the public.

The accompanying statement and chart, prepared by Mr. Jump, the budget officer of the Department of Agriculture, gives the clearest possible picture of how money appropriated to the Department of Agriculture is used:

Expenditures of the Department of Agriculture for the fiscal year 1931, on basis of budget statement No. 2, pages A32–A47 of Federal Budget for 1933

			Per cent.
1. *Roads*			
Federal aid to States	$158,322,940		
Forest roads and trails	18,831,020		
Mt. Vernon Highway	3,392,959		
Total for above roads		$180,546,919	57.98
2. *Emergency drought loans*		48,824,743	15.68
3. *Payments to States:*			
State experiment stations	4,340,000		
Extension work	8,650,229		
Forest fire prevention, etc.	3,434,033		
Total payments to States, as above		16,424,262	5.28

			Per cent.
4. *Ordinary activities of Department, including*			
(a) Some of the larger items of public interest, as follows:			
Weather Bureau (general)	2,745,834		
Weather Bureau (for aviation)	1,241,627		
Meat inspection	5,592,190		
Food and drug laws	1,614,666		
Forest Service	14,979,336		
Biological Survey	1,956,515		
Tuberculosis eradication	6,252,744		
Total above items (11.04 per cent.)	34,382,912		
(b) Remainder (10.02)	31,201,357		
Total for ordinary activities of departments		65,584,296	21.06
5. *Total, Dept. of Agr., all purposes*		311,380,193	100
Less checks issued but unpaid June 30, 1931		14,514,248	
6. *Net cash withdrawal from Treasury*		296,865,945	
Total expenditures of Federal Government withdrawals from Treasury, net cash, including payments from postal revenues		4,877,315,309	
Relation of Department of Agriculture expenditures of Government:			
All purposes, on basis of net cash withdrawals ($296,865,945)			6.09
Deduct roads and drought loans, leaving		82,008,531	1.68
Deduct roads, drought loans, and payments to States, leaving		65,584,269	1.34
Deduct roads, drought loans, payments to States, and certain of the larger items of general public interest, as listed above, leaving remainder of 31,201,357			0.64

THE OBLIGATION OF UNIVERSITIES TO THE SOCIAL ORDER[1]

THE UNIVERSITY AND GOVERNMENTAL CHANGES

By Dr. HAROLD GLENN MOULTON
PRESIDENT OF THE BROOKINGS INSTITUTION

THERE is expressed in the very wording of the subject before us, "The University and Governmental Changes"—a wording for which I am in no degree responsible—a social philosophy which may well serve as an introduction to our entire discussion. In this pragmatic conception, governmental structures, even principles of government, are evidently viewed as subject to a continuous process of adaptation to the needs of an evolving economic and social organism. Before beginning this evening's discussions of the relations of the university to the changing problems of government, it may perhaps be useful for us to recall that there are two fundamentally different conceptions of the province of government. If we adhere to one of these theories, the part that the university might play is negligible; but if we accept the other, the opportunity of the university—and indeed its responsibility—is most important.

The first of these conceptions is that the government should play a passive rôle in human affairs. The origin of this philosophy of government may be explained as follows: The gradual emergence of the scientific spirit and the formulation of laws pertaining to the physical world exerted a profound influence upon men's ideas in other realms of thought. Was man, the creation of God, not as much a part of and as subject to an ordered universe as the physical earth on which he had his setting? Principles of human action of universal applicability were sought—and they were in due course conceived, if not discovered in any scientific sense. Blackstone, for example, contended that there had been established by the Creator a simple system of natural law or ethics and that "the constitution and frame of humanity" had been so contrived that if we but pursued our own "true and substantial happiness" we could not fail to be in tune with the universe of nature. Moreover, each of us in pursuing and achieving his own happiness unwittingly but inescapably promotes the happiness and well-being of his fellow men.

Oppressed by the restrictions upon individual freedom which characterized the eighteenth century, Rousseau declared all social institutions vicious in their effects upon free-born man—stifling everything natural in him and giving him nothing in return. "Civilized man is born, lives, dies in a state of slavery. At his birth he is sewed in swaddling clothes; at his death he is nailed in a coffin; as long as he preserves the human form he is fettered by our institutions." Said William Godwin: "Reason is the only legislator, and her decrees are irrevocable and uniform. The functions of society extend not to the making, but the interpreting of law; it can not decree, it can only declare

[1] Addresses at the conference of universities sponsored by New York University and held at the Waldorf-Astoria on November 15, 16 and 17, 1932.

that which the nature of things has already decreed."

In the light of these conceptions of natural law the functions of government were reduced to the simplest terms. At the most the state should seek to suppress or redress wrongs against individuals and to provide for common defense against foreign foes. The greatest merit of this reasoning lies in its emphasis upon the life of the individual citizen. The focal point of interest is human beings, and the goal is the unleashing of individual energies to the end that we who inhabit the earth may realize our potentialities in fullest measure.

Although the ideal of individual freedom from the so-called tyranny of government was never fully realized, under the influence of this conception of natural law, universal and unchanging in character, the very foundations of government throughout much of the western world were profoundly modified. Innumerable laws, inimical to the freedom and to the initiative of the individual, were repealed, and industry and trade were relieved from a multitude of hampering regulations. International relations were also profoundly influenced by the removal of restrictions against the international movement of trade and specie and against the migration of people from country to country.

While the remarkable changes in economic organization during the last half century or so have greatly affected our ideas as to the rôle which government must inevitably play under modern conditions, the traditional philosophy on which we have been reared continues to dominate our thinking. The crystallization, during the past few generations, of these conceptions—both of government and of the economic world with which government is primarily concerned—has tended greatly to restrict our mental horizons and to render us far from scientific in outlook. At the most, the philosophy of government which we are discussing has been in actual application for only a brief interval of time and then in but a portion of the world. Political science, if it is to be animated by the spirit of science, must be limited neither by the calendar nor by geography; it must be timeless and spaceless, embracing within its domain the experience of all countries and all epochs.

Over a substantial part of the world, even during the eighteenth and nineteenth centuries, and over most of the world throughout recorded history, a view of the rôle of government other than the passive one which we have been considering has prevailed. This is the conception of the state as an active instrumentality in economic and social development. The government, whether monarch or parliament, under this theory seeks to direct and foster economic activity, or even to organize and control economic enterprise.

In the feudal era, to go no farther back in history, all society was organized and directed from above. The government, that is, the king, was supreme, and he ruled the people in the interests of what seemed to himself desirable ends. Vassals and villeins were servants of the lord and king and exchanged fealty for protection. Free enterprise, as we know it, was unknown—the entire economic system being organized from the center out. This same philosophy was paralleled in the development of church polity and canon law.

After the passing of feudalism, the conception of government as an active directing agency in the control of economic development remained over a large part of the civilized world. Aside from the countries of Western Europe and their colonial offshoots—for reasons already indicated—and from China and India—for other reasons—the govern-

ment has continued to play a very active rôle in economic affairs. In varying degrees, in Russia, Turkey and the Balkans, in Central and Southern Europe, in South America and in Japan, the function of government as an active directing agency has never been abandoned to anything like the extent that it was given up in Western Europe under the influence of the natural law philosophy.

The founders of modern Japan, for example, were nation planners and builders in as true a sense as are any of their modern prototypes. They set up a series of national objectives and then proceeded in systematic fashion to develop the ways and means for reaching these objectives. It was thought necessary to develop railway, telegraph, telephone and postal services; to stimulate shipping; to foster industrial development; and to promote the more effective utilization of natural resources, including agriculture, forestry, mining and fisheries. In carrying out this program of national economic development, the central government played a rôle of primary importance—such government leadership being consistent with, and the natural growth of, the principles of feudal organization which existed in Japan until 1872. There was here no tradition that the rôle of government in economic activity should be a passive one, with reliance upon private enterprise to furnish the drive required for progress. If economic progress were to come and come quickly, it was assumed as a matter of course that the government would have to set the pace. The Japanese system has remained essentially one of state socialism.

Similarly, the government of Germany has exerted a profound influence over the direction and character of economic development. This has been accomplished by means of the control of transportation, by subsidies to shipping, by systematic encouragement to agriculture, by protective and other commercial policies, and by the mobilization of financial resources for the furthering of national objectives.

In recent years, governments everywhere have been rapidly extending the scope of their activities in connection with economic and social affairs. In Russia, state direction assumes one extreme form, and in Italy another. Elsewhere in Europe we find that the influence of government over business is being constantly extended, and that new government agencies in the form of economic councils of one type or another are being set up for the purpose of coordinating and guiding the economic life of the nation.

Even in the United States, the government has come more and more to influence and control economic activities in the light of what are regarded as wise national policies. The avowed purpose of the tariff and other commercial policies has been to develop within this country a more diversified and many-sided economic life than might otherwise have existed and to give to the American people a standard of living which, it is contended, could not otherwise have been realized. We utilize hundreds of millions of dollars of public money in developing ocean shipping and certain forms of internal transportation, the government even engaging in the operation of barge lines on the Mississippi for the ostensible purpose of demonstrating to hesitant private enterprise that it has here overlooked a golden opportunity. We spend other hundreds of millions of taxpayers' money in the attempt to overcome economic forces as related to agriculture. We seek to foster export trade by means of the promotional services of government departments and by special legislation. In various social ways, also, the government seeks to protect as well as to promote the welfare of the people.

It is, however, in time of national

crisis that the power of the government is invoked most actively in the furtherance of business enterprise. In the last three years, for example, people everywhere have looked to the government as the only agency that might restore prosperity to distressed industries and employment to the people. It has, moreover, been deemed necessary, even by a political party which extols most highly the principle of individual initiative and unrestricted private enterprise as the foundation of American progress, to utilize the financial resources and the credit of the government as a means of preventing the disintegration of the entire financial system.

It is evident that, in the western world, the cycle of time has brought us back pretty soon to where we were in the heyday of mercantilism. Whether we like it or not, we are having in increasing measure with each passing year an extension of the rôle of government in organizing and directing economic activities. If we accept the fact that throughout the world government does and inevitably must play a significant rôle in economic and social development, we are challenged at once by one fundamental question, namely: What will be the ultimate consequences upon the lives of individuals? Will such a system in the long run generate those creative influences which are essential to social development? Will each and every individual be able to realize his potentialities as well in a society in which the government plays a rôle of supreme importance? These questions are as pertinent now as they were in the time of Blackstone and Adam Smith. This issue is the fundamental one in the Russian and Italian experiments.

A large measure of government participation in economic and social development does not, it seems to me, necessarily mean that the development of the individual will be arrested. Everything depends upon whether the government is autocratic in character or democratic in its organization and in its methods of operation, and whether the objective of enriching human life is borne consistently in mind. It may well be possible so to organize our government machinery and so to enlist the interests of citizens in the affairs of their government—national, state and local—as to stimulate the development of individual capacities in ways and to a degree hitherto undreamed.

I think it may safely be asserted that on the whole the professional political scientists of the universities have contributed relatively little to the development of instrumentalities of government—most of our political principles and our governmental organization and procedure emanating from constitutional conventions or legislative bodies. The primary reason for this is that the political scientist has until very recently been under the spell of the eighteenth century. He has been interested chiefly in discussing the evolution of political literature and in describing the structure of existing governments. The fact that much the same charge may be made against the professional economist does not alter the truth of my contention about the political scientist. There has been almost no attempt on the part of professional students to reappraise the possibilities of government as an agency of social progress or to determine whether our existing government organization and agencies are performing with reasonable efficiency the functions which they are supposed to perform.

If we are to make significant contributions in this direction, it is essential that the work of university departments of economics and government be closely coordinated. The need of close cooperation here is much greater than between other divisions of the social sciences.

In the laissez-faire era, economics was not in any way concerned with government; it was merely an analysis of the working of economic forces under conditions of unrestricted competition, and political science was concerned with the divisibility of sovereignty rather than with the control of public service corporations. As conditions have changed, it is true that both economists and political scientists have become increasingly aware of and interested in the manifold interrelations of government and economic enterprise to-day, but they have in no sense joined forces in grappling with these problems. By virtue of their restricted training, both the economists and political scientists are seriously handicapped in analyzing any of the complex problems relating to government control of economic activities. The economist does not know enough about governmental organization and the political scientist does not know enough about business and economics for either to function with genuine effectiveness.

The experience of government departments and bureaus, of business organizations and of research agencies, alike, indicates that the vital need is for men more broadly trained than those of our generation in the related problems of government and industry. I submit that the desired result can not be obtained merely by giving a graduate student of political science a number of courses in economics, and vice versa. There must be a new and frontal attack made by departments of economics and government jointly on the problems in hand. Gradually, the entire curriculum of these departments must be organized around a common objective. Only thus shall the work of present scholars be given the greatest vitality, and only thus will we secure the type of future scholar and statesman which is required if the complex economic and government organization of our day is to be effectively utilized in the service of society. Here in this field of training lie, perhaps, the most distinctive opportunity and the greatest responsibility of the university in relation to the changing problems of government.

The opportunity for fruitful research in the problems of government has never before been comparable with that which exists to-day. Time permits but the barest mention of some of the more important problems awaiting scientific study.

First, I would suggest a reappraisal of our comprehensive system of federal, state and local governments, and their interrelations. This general plan of government, and the allocation of functions and responsibilities which it carries, was established 150 years ago by men who naturally thought in terms of conditions existing in their day. It was before the age of railways, almost before the era of interstate commerce. Such industry as existed was organized and financed locally, and there was nothing resembling a national banking or credit structure. The principal public utility apart from the stage-coach was the town pump. Inevitably, the embattled farmers of 1789 thought of government primarily in local terms, with the state the largest unit necessary for almost any purpose other than the common defense. The size of the intermediate county as an administrative unit was determined by the limitations of horse-and-buggy locomotion.

Under the conditions of to-day, this system is in many respects no longer defensible. It results in no end of conflicting policies and regulations, it is extremely expensive, and it retards economic and social progress. Accordingly, there is imperatively required a reintegration of this entire system. The new division of functions and the changed relationships required can not

be determined by any arbitrary formula for national, state or local standardization. They must be worked out in the light of a coordinated series of studies bearing upon the various issues involved. We must seek to ascertain what types of problem by their inherent nature require federal regulation or control. What ones lend themselves most naturally to regulation by the state? What ones (bearing in mind the ultimate objective of enriching the life of the people) may best be dealt with by the various local governments? The question must also be squarely faced whether some of the numerous administrative units which have been handed down to us are required under modern conditions.

Second, in the particular domain of the national government we need—in addition to studies directed toward promoting economy and efficiency—a reconsideration in the light of present conditions of certain basic problems of government organization and procedure. Mention may be made of the system of party government; the division of powers and the principle of checks and balances; legislative organization and procedure; the administration of justice; and the functioning of independent and quasi-independent commissions, many of which have been shouldered with both administrative and judicial functions and are so overwhelmed by a multitude of detailed issues that they are unable to fulfil the major purposes for which they were created. Among the various departments and bureaus of the government there is not only much overlapping of function, there is also working at cross purposes. Reorganization is required not only for purposes of economy but quite as much in the interests of carrying out coordinated and consistent national policies.

In the field of the state, the entire governmental system, typically speaking, needs overhauling, including in many cases a revision of the Constitution itself. Economies of great practical importance can be, and in some cases are being, realized through fiscal reforms and the establishment of adequate systems of financial control. Equally important results can be obtained through the reorganization of state government departments and agencies and the articulation of their activities in relation to a series of major state objectives. The time is ripe, at least in a number of states, for fundamental studies of the interrelations between state and local government and the economic, social and educational problems with which the people are so vitally concerned.

It is on the basis of studies such as these, and on this basis alone, that the economies in government expenditure now so urgently required can be intelligently made. Hysterical demands for economy by a tax-desperate electorate may easily become mere parsimony and result in crippling basically important state services, including education. Unless perchance there is substantial improvement in general economic conditions in the relatively near future, we must view the financial problem of state and local governments with keen apprehension. There is here a great immediate opportunity for the universities, particularly the state universities, to render practical, constructive service of great importance. Fortunately, in a number of cases the opportunity for such service has been embraced, by private as well as by state institutions. Aside from the benefits which may accrue to the state, such studies yield large dividends to science by bringing scholars into intimate contact with the real problems of government—by providing them laboratories in which to work. Those who pin their faith to the lonely thinker, working in isolation far from the busy

marts of trade or the arena of politics, seem to me to ignore the fact that it is just as necessary for the social scientist to check his thinking by laboratory observation or experiment as it is for the physicist or biologist. The laboratory of the social scientist is the world of business and government and social relations. The great contributors in social science have been those whose thinking has the touch of reality because they have drawn heavily from the lessons of human experience.

Third, it is necessary for us to take stock of certain principles, procedures and devices which have been developed in recent years with a view to enabling the public to participate more extensively, more intelligently and more directly in the processes of government. I refer to such varied expedients as the direct primary, short ballot, and the initiative, referendum and recall. We need to know whether the direct primary has resulted in giving us a better type of public official; what has been its effect upon the executive's power of leadership in legislation; whether it has scattered party responsibility and destroyed party discipline, and if so whether there are compensating advantages. With reference to the initiative and referendum, we need an appraisal of the effects of such measures not only upon the character of legislation, but also upon the people's attitude toward, and interest in self-government.

We have accumulated a wealth of experience on all these problems, but as yet there has been no systematic attempt to appraise objectively the actual results achieved. Here and there special studies are made of some particular aspect of this problem of popular government or of its success or failure in some particular jurisdiction, but we have had nothing like a general appraisal of these instrumentalities and devices.

Similarly, we have thus far given surprisingly little attention to the experience of foreign countries with various devices and agencies of government. In books on comparative government we find detailed descriptions of the structure of different government systems; but there has been little study of the relative merits of alternative methods or devices for accomplishing given ends. What, for example, are the advantages, if any, of the system of administrative courts developed in various European countries, and could such courts be readily adapted to American conditions? What are the merits, if any, of the European system of delegated legislation? What light does the experience of other countries throw upon the problems of government ownership or regulation of various types of public utilities, and the utilization and conservation of natural resources? What light does the British and Japanese experience, for example, in the centralized financial administration of local units of government throw upon the American system of administering local finances?

In the light of this brief outline of the nature of the changing problems of government with which we are concerned, I should like to close with a few comments as to the magnitude and character of the research problem that is presented. I have already laid emphasis upon the necessity, in connection with many of these problems, of utilizing men with specialized training in more than one division of the social sciences. I wish now to stress the necessity of a concerted attack upon the problems before us. So rapid has been the pace of technological progress and so extensive and complex have been the resultant changes in the problems of government that a cooperative program of research has become a primary necessity if our investigations are to be of other than historical interest.

In some cases, this cooperation might

be worked out in terms of functional division of labor—individuals from one institution concentrating on one phase of a problem and those from another on a different phase; while in other cases cooperation should be developed on a geographical basis. Such problems as the direct primary, the initiative and the referendum have been experimented with in a score or more of states. It would seem to be the part of wisdom to enlist the interest of a group of institutions or individual scholars located in different parts of the country in making a united attack upon such problems as these. The objectives and the methods of the study could be determined in joint conference; the experience of each state could advantageously be studied by a scholar resident within that state; and the results of the series of studies could finally be subjected to a joint appraisal by the various collaborators. The results of such comprehensive investigations might well be accepted by the public as conclusive in character.

That such cooperative research presents difficulties is readily apparent. But if we are to discharge the responsibilities which our training and the financial support accorded by our institutions impose upon us, we will resolutely face these difficulties and endeavor to overcome them.

OUR UNIVERSITIES IN AN UNSETTLED WORLD

By THOMAS W. LAMONT

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INASMUCH as this is an academic gathering, let us first consider what a shocking series of world events has been spread before the innocent gaze of our American youths who, born at the outbreak of the great war in 1914, entered only last September the portals of New York University and our other colleges.

For the first four and a half years of the childhood of this freshman of to-day he would have witnessed a world given over to wholesale slaughter. In that conflict were killed thirteen million able-bodied men. Twenty million more of them were disabled. Disease, privation and destitution accounted for the loss of six or seven million of civilians. There was a total of perhaps forty million people put out of constructive endeavor. In a material way thirty billion dollars of property were wiped out. In national debts an increase from about twenty-eight billion dollars to two hundred and twelve billion dollars—a terrible millstone around the necks of the burdened populations.

At the age of five this American boy would have seen in the Versailles Treaty new states set up on uneconomic lines; a militant peace filled with resentments and the seeds of new misunderstandings.

THE STRUGGLE OVER REPARATIONS

And then that boy, from the age of five until now when he is eighteen, would have gazed upon an economic warfare waged in Europe, more destructive to commerce, to stability and to an ordered life than the great war itself. That phase will be known in history as the struggle waged over German reparations, a conflict that helped to bring Europe to the verge of general bankruptcy, ending only with the notable agreements reached at Lausanne last June.

During all those earlier years from 1919 to 1925, or beyond, this innocent youth of ours would have witnessed

(alongside the conflict over reparations) the pathetic and heroic endeavors of mankind to reconstruct a shattered world. He would have seen the piecemeal efforts by which Austria, Hungary, Bulgaria, Greece and other countries were set upon their tottering feet; and by which Germany, after complete debacle of the currency, had been reestablished under the Dawes plan. Other countries were slowly toiling back to the gold standard—Great Britain in 1925, France in 1927 and 1928, Japan in 1930. And again our sub-freshman would have been shocked to see the most powerful of these countries, Great Britain, only last year driven to abandon once more the gold standard; and since then forty other countries of the world either follow her example or place embargoes on the shipment of gold.

Meanwhile, as to politics, in almost every country radical changes of government were taking place. "The old order changeth, yielding place to new." Kings and hereditary potentates went almost completely out of fashion. On the continent of Europe revolutions were not infrequent, and in South America they became the order of the day.

And during all these years this American youth of ours would have witnessed other phenomena of almost equal portent. He would have seen the fantastic attempt by many nations to peg the prices of commodities—wheat, cotton, silk, rubber, coffee and a dozen others. He would have seen the unbalancing of government budgets on a wholesale scale and the fatal resort to inflation of the currencies.

Increasing War Budgets and Taxation

What came next? The increase of war budgets of the leading nations. Instead of diminishing with the reduced national incomes, these budgets increased by 1931 to 65 per cent. above the average figures for the five years preceding the Great War. The burden of taxation in almost every civilized country, including our own, has become increasingly and intolerably heavy. Our eager youth would have seen tariff barriers built up on every side, with our own country in the lead—barriers which all over the world prevent that very exchange of goods and facility of commerce which are essential to the restoration of world prosperity. He would have gazed at those great stores of gold, shipped clumsily and extravagantly back and forth across the ocean; a total in the last four years alone of almost four billions of dollars in and out of this country.

There is another phenomenon of the times which has rapidly and alarmingly developed. That is the growth of an intense nationalism in every part of the world. Almost every separate people has sought to shrink within itself; to dig itself into its own cyclone cellar and endeavor to save itself, come what might to the rest of the world.

Yet despite that reparations warfare that was going on in Europe for thirteen years; despite all those artificial barriers that were being raised against world recovery; here in America under the early stimulus created by the war's wholesale destruction of goods we were beginning, during the middle years of this last decade, to enjoy a singular prosperity. Our factories had been stimulated by the wartime demand from overseas for our goods. There came to be plenty of work for almost every one and plenty of people to buy. There was a brief recession of business in 1920 and 1921. Many persons believed erroneously that it had been sufficient to liquidate fully the economic effects of the war. At any rate, America's natural resources, intense energy and resourcefulness again came to the front and created the beginnings of our boom times.

Our Foreign Trade Policies

Acting, however, upon a deliberately

adopted national policy, we tried to buy as little as possible from the foreigner. But we were keen to sell him our goods. So in order to sell him, we proceeded to lend him the money wherewith to pay us. From 1922 to 1929 American investors and institutions lent abroad approximately six billion dollars net. American banks and bankers have been sweepingly criticized for arranging such loans. In certain cases criticism as to lack of care in investigation and method has undoubtedly been justified. But the general movement was a natural one, forced on the investment community by reason of our national policy of buying abroad as little as we can, and of attempting to force on the foreigners all the goods we can possibly sell them.

Thus during those years from 1923 to 1929 the American community proceeded to complete what seemed like the charmed circle, and then began to make it whirl. The formula was a simple one: The more money we lend to the foreigners, the more of our goods they will buy. The more they buy, the more we shall manufacture. The greater the demand becomes, the more we expand our factories and equipment. The more we manufacture, the higher prices go. The higher prices go, the higher wages rise. The higher wages are, the greater becomes the public's purchasing power. Everybody has a job. Millions of dollars paid in salaries and wages are put to newfound uses; quicker ways of transportation; delightful means of communication; all sorts of alluring devices; most of them tending to increase the material satisfactions of life, but not leaving a sufficiently large proportion of savings laid by for the rainy days. And for the workingman it has rained almost steadily for the last three years.

The Great Speculative Orgy

Then, starting about 1925, from small beginnings came the grand American speculation. Our people from one coast to the other were seized with a desire to get something out of nothing. They did not want to invest for income. They wanted to buy for profit. Speculation spread in commodities, jewels, real estate and securities. For a while it all seemed so easy. Stocks go up on the stimulus of purchases. The higher they go, the more new purchasers come in. The more fresh buyers there are, the higher the stocks go. It is a great and exciting game—jumping on this endless-chain escalator, constantly going faster and higher.

Then came the collapse from prosperity, a change in this country after a few short months to days of depression, deflation, failure and, in so many instances, of despair. Just as a side-show, we display to these young people of ours other phenomena—shaky banks, failing banks, hoarding of gold—all the outward evidences of panic. This was as recently as a short year ago and less, although now that phase is fortunately at an end and confidence is restored.

Those, then, are some of the pictures spread before the guileless eyes of our American freshmen who have never been privileged to see anything of a world that we elders would term normal—those youths from the age of nine to fifteen looking out upon a seeming world of domestic prosperity and gladness, and then from fifteen to eighteen watching millions of people walk the streets looking for jobs, demanding the shelter and food which must be furnished to them.

A Return to Constructive Effort

But let us now turn to the other side of the picture. The panic of fear has subsided. Normal processes get under way. Gradually we see again the genius of the American people come to the fore. Efforts, systematic and gigantic, have been started and are now beginning to work. Almost the whole community seems banded together, determined, first of all, each man to help his fellow; de-

termined that no one shall perish from lack of food or shelter. Manifestly, and with renewed confidence on all sides, men are exerting their best efforts towards reconstruction. Government co-operation has come in upon a grand scale and in a score of different ways. Things gradually begin to straighten themselves out. The deflation of commodities seems almost at an end. Hard work begins to fill up the gaps. The fingers of a new dawn stretch their tips above the horizon. There are signs of betterment decidedly more tangible than mere hope.

In the midst of our efforts for avoiding shipwreck, for saving those already on the rocks, we hardly have had time to study whence the storm came. Yet questionings have already begun on an active scale. Each one of us is looking around for a scapegoat. Why do my pet investments which paid me 6 per cent. go down in price from 150 to 15 and now pay me no return? Was it the fault of the broker or banker? He answers: "No, we may have been no wiser than anybody else. But certainly the chief loss has been due to the severity of the depression which has caused heavy depreciation in the soundest of American investment securities."

Governmental Extravagances

Is our trouble due to government extravagance? In a certain measure, yes. Money was being spent so freely, taxes were being collected so rapidly that all our governmental bodies fell into the easy habit of spending money like water. New York City's funded debt has grown in ten years from eleven hundred million dollars to eighteen hundred million dollars. Its annual budget has increased in the last ten years from three hundred and thirty million dollars to six hundred and thirty-one million dollars. As to the Federal Government, with the budget out of balance, the Congress has very properly been obliged to levy heavy new taxes, adding to the serious burden of taxation that had been arranged on a generous scale when there was ample income to pay the bills.

Others of us have another alibi. We have found a scapegoat which can not kick back. It is the devilish foreigner who has done all this to us. He got into a frightful mess and hauled us into it. He borrowed our money and then went bankrupt, or almost bankrupt, and a good part of the loss he has never paid back. He fell into a panic in Central Europe, and the panic, like a prairie fire, jumped over here. This is a difficult alibi to sustain, by reason of the fact that Europe's crisis in the spring of 1931 came eighteen months after the American collapse of October, 1929.

The War Debts a Factor

Other people have found still a different scapegoat, the anatomy of which is well worth examining: It is Congress, and behind Congress the American people, which for years has insisted upon the foreign governments paying us the perfectly just—perfectly just, I say—but impossible war debts. We have held to the idea that these great overseas payments, representing in general nothing except exploded shot and shell, shall be paid every year—a quarter of a billion dollars each year—an unnatural stream of payments, choking the channels of world trade.

Incidentally, it was perfectly reasonable that the Allied powers should expect and demand that Germany should pay sufficient to repair the physical damage wrought by her armies in Belgium and northern France. But the bill has not been paid in full, nor can it ever be so paid. Similarly, people are asking: will it ever be possible for the unwieldy war debts—undertaken no doubt with reasonable expectation on both sides that they would be discharged—ever to be paid in full at Washington?

These, then, have been some of the

phenomena which world civilization has presented to the wondering eyes of our youth for the first third of the twentieth century. My purpose has not been to discourage you, but just for a few minutes to let this vivid panorama unfold itself before your eyes. To our elder view, accustomed to the various ups and down of this life, having seen former panics and former depressions, the spectacle, terrible and prolonged as it has been, is perhaps not quite so startling as it would be to the inhabitants of another world.

We can lay our difficulties at the door of no one person; no one group of persons; no one government. The greatest, single underlying world-shaking cause of the depression has been the war, its prodigious losses, its repercussions, its dislocations, its unsettlement of morale, including speculative orgies—war and the unwisdom of man who permitted that war.

Various Political Ideas

What is the remedy for the world's present situation? Many among us, without adequate regard for some of these manifest causes of the depression, are declaring that the whole economic system of civilization has broken down once and for all and should be thrown into the discard. Is then the answer to be a grand leap into Socialism? Or a somersault into Communism? My answer is "no." Before we move in this direction we can well afford to observe and profit by other people's mistakes, or perchance by their successes.

Is the remedy one great plan of economic organization, something that will surely balance world-wide production and consumption to a nicety and always provide work for every one? That is the Utopia that the world may work towards. But there is no swift and royal road to universal prosperity. We have to rely not on gods, but on men, to devise, plan, organize and execute. And we must rely upon them with their limitations. In general terms, we can say that the American economic community has done far more extensive planning than it ever did forty years, or twenty years ago. We have seen, however, how far it has fallen short. Yet that does not mean that, while in the modern world we may well have come to a turning, we have come to the end of the road.

Not Revolution but Evolution

No, I am one who believes that we must rebuild on the basis that is still under us. We must, in Mr. Lippman's phrase, continue to live in the house while we are rebuilding it. You may call that house, if you will, the capitalistic system. It has been in the building since the Dark Ages. It has, with all its ups and downs, brought to mankind increasing comfort and happiness. It is still a fairly tough structure and will not easily topple over. But it has developed some serious weaknesses which require more than patchwork attention.

Why the Younger Generation is Radical

Realization of that fact brings us back to these universities of ours. I hear complaint that our college professors are teaching too much of socialistic theory. That would not be my observation. These are days when among the teaching forces of our institutions the freest sort of academic freedom should prevail. But to me it is little wonder that many of our students to-day are radical, are joining the Socialist party or are even looking with a kindly eye upon the allurements of Communism. The sort of world that they have seen is the one of chaos that I have described. They know no other. The modern world that existed prior to 1914 is as unreal to them as the age of chivalry is to us. In a world of flux they want something that they can cling to, hold fast to. And they eagerly embrace what seems to

them the solid faiths which assume to have solved all our questions.

It is the growth of science that is perhaps the most encouraging single feature of our modern civilization, going far to offset its present failures. The discoveries of science are, as we all know, constantly tending to strengthen and prolong life. The luxuries which science creates give us, in turn, time for more science. We see on every side scientific discoveries (I am not alluding primarily to mechanical development) being made by men studying purely for science' sake; workers going on quietly and steadily in their laboratories, regardless of a changed or broken world.

If, then, a purely man of affairs can presume to speak on an academic subject; if thus I were to make a plea to our universities—to both students and teachers—it would be to set up the scientific method as a goal to almost every end. In training the mind of our youth, in teaching the student to think and to use his mind as he would a finely tempered tool, we should urge always the practice of the scientific method. That method proceeds by experimentation, by making a disinterested search for truth, by getting the facts and seeing where they lead. Imagination constructs the hypothesis. Then we verify or check the hypothesis to see if the thing works.

The Maintenance of an Open Mind

This means that no fixed and static dogmas can necessarily stand unchanged in a changing world. They must give way to fit the altered conditions. Our university can give the student the spirit of this scientific approach to most efforts of human endeavor; not only to the realm of abstract knowledge, but to a vast number of the practical affairs of every-day life, to sociology, religion, business, politics, government. Our university can give its students tolerance, so that they will not condemn an idea offhand, because it is new or because it is old. It can help them to develop that tempered judgment which is the beginning of wisdom.

And as I would urge the scientific method upon teachers and upon these new students of ours, just on the threshold of the university, so would I urge upon myself and upon my associates in the world of affairs to turn away from every form of bias; to examine with unprejudiced eye any new economic system or change of our present system that may be proposed; above all, to get away from that rigid nationalism which has proved so crippling.

The Folly of Economic Wars

But I beg you will be under no illusion as to my own individual convictions, unimportant as they are: No economic system whatever—old or new—can be devised which shall be proof against the folly which mankind has shown. In 1914 to 1918 white men engaged in a titanic struggle of self-destruction. It was the first war of populations. Previous wars had been wars of champions. In the great war the whole economic power of the populations of the countries engaged was enlisted.

When the war ended the statesmanship which led the world was exhausted, neurotic and embittered; with the consequence that the treaties of peace brought no peace, but erected fantastic new barriers to peace, political and economic. Unwarranted frontier changes, and anomalies like the astronomical reparations claim, left bleeding wounds in the body of mankind. Looking back we now see that it was inevitable from these peace settlements, which were no settlements that the war should not stop but should be transferred, as it has indeed been, from the military to the economic field. Here America has been one of the leaders in the economic war. In the two drastic tariff increases of 1922 and of 1930 she set standards for the

strangulation of trade which other weaker nations felt compelled to emulate. Thus, the four years' war on the battle fields of France has, as I have already pointed out, been continued by a fourteen years' economic war on a world-wide front.

The World's Interdependence

Remember, after all, that we are in a world of men who, all over the globe are singularly alike in their passions and prejudices. Just as we have seen this depression to be world-wide, so every country is dependent in part on the misery or the good fortune of every other country. Even America, with all her magnificent resources, can never be wholly self-contained.

Remember, again, that we are now on the threshold of a new stage of progress and that America must lead the way. It can go far on that way only by realizing that it is a part of the world; that the world also must move with it to new recoveries and new stabilities. Our primary remedy for present difficulties is not in the change of economic systems. It consists in an enlightened public opinion which will demand of our rulers that they seek peace, economic as well as political, and pursue it.

SPRING DAYS IN ZUNI, NEW MEXICO

By Dr. ELSIE CLEWS PARSONS
HARRISON, NEW YORK

We motored in from Gallup over the new road, in two hours. Twenty years ago I once made the trip in a wagon in eight hours, by the old road which is five or six miles shorter; but that day snow was deep on the ground, and more was falling and it was so cold that the lips of the Governor were blue until I broke the excise law and gave him a drink from my flask. That was before prohibition for Whites, but not for Indians, and the week before, Shalako night, I had gone around with him and the Farmer as they confiscated the white mule, a hundred bottles or more, from the visiting Navaho. But a snow-storm makes its own conditions, and I knew the Governor had become a staunch prohibitionist, as were all the Pueblos just at that time—they are not to-day.

This year even the new road had been passable for only two weeks, because of the great snows of the winter when food had been dropped from aeroplanes for the marooned Navaho and a Zuñi perished on his way back from picking piñons in the mountains. In October a party of Zuñis had visited the Hopi to dance Kachina, and the devastating snow-storms were imputed to their rain or snow making dance—it had been too successful.

The dance-visit had been suggested by the new Kopekwin, the son of a Zuñi-Hopi father. It was from his father, no doubt, that the Kopekwin had heard of the old custom of visiting the Hopi in late autumn to dance Kachina. The custom had lapsed since the close of the last century.

I asked the Kopekwin when the next initiation of the boys into the Kachina society was to occur. A year ago, in the spring of 1931, the last initiation took place; one hundred and twenty-five boys were initiated; one of the six kiva groups, Hekiapakwe, which had been much depleted, was again vigorous, much to the satisfaction of the entire pueblo. He did not know about the initiation date, answered the Kopekwin, he had much on his mind—he, more than any one else, determines the year's dance program. Besides, he was worrying about the future of his fraternity, the Shi'wannakwe. The Shi'wannakwe is the "oldest" of the thirteen fraternities or curing societies of Zuñi. Its chief has to be a member of the Badger clan and of a particular maternal family within the clan. Now the only one in the Kopekwin's family who could qualify for the position was his own brother and he was not a member of the Shi'wannakwe fraternity.

The Kopekwin was also disturbed about one of the houses in which a ceremonial group is to be entertained at the next Shalako or Advent of the Kachina, the masked dancers. In late November or early December eight new houses or rooms are "blessed" by impersonations of the Spirits or Kachina, who bury prayer-sticks below the earthen floor. The householder who had volunteered to entertain the Sayatasha group was in bad repute. She was a Laguna woman married into Zuñi—many times—and the last time she had entertained the Sayatasha group, gossip had it that she had sold the prayer-sticks from under her floor. Perhaps she would do it again. Had the Kopekwin been in Zuñi at the time her husband went and got the stick of appointment, *i.e.*, when her offer to entertain the Sayatasha was accepted, the Kopekwin would never have agreed to it. The Sayatasha group

consists of five impersonators. Two of them had refused to serve because of the scandal about their prospective hostess, and their places had to be filled by others.

A departmental row, dishonesty in office, failure of family successor, miscarriage in weather control which meant loss of crops (the corn could not be harvested until January and was partly spoiled), of sheep and of one human life —no wonder the Kopekwin was worried and looked it, as he sat there waiting idly for his meal. Because of his position he could not be asked to cut wood or do any of the chores a self-invited guest may be called upon to do.

There are still other matters the Kopekwin and all the older men of Zuñi have to worry about. The Laguna woman is not the only seller of ceremonial objects; the only ex-service man of Zuñi is said to be another and on such a scale that he can afford a car. "We do not know where he gets his money," is said of him, which is the pueblo way of saying, "we very much suspect he has been doing something he should not do." It is becoming increasingly difficult to get young men to impersonate the Shalako, one of the most exigent of the ceremonial rôles, for it is a year long devotion of visiting distant shrines and memorizing prayers. "The young men are lazy," commented a critical girl, a half-breed. "No, my dear," I rejoined, "they do not believe." "Do you believe the Sun will help you if you pray to him?" I asked the girl's brother, a leader in the Returned Students' Club. "No, I don't," said he. "And you don't believe in the White people's god, either, do you?" "No, I don't."

Over a hundred years ago the Franciscan Fathers departed from Zuñi, but within the last decade the mission has been reestablished and has been maintaining a school. At first the return of the Catholics was bitterly opposed by all, excepting a small group of townspeople led by Jesús, a Yaqui Indian who had been captured as a child and sold into Zuñi. The girls would not come out to dance for the Saint, although the Saint had been cherished through the century as much as the other fetiches of the town. But the returned Fathers and black-habited Sisters whom the Zuñi call crows have been wise during these years; they have interfered little if at all with the older people, directing their attention to the children, working towards the future. The native hierarchy is unaware of Catholic or modern pedagogy, "give me a child up to the age of seven," implies for them neither threat nor promise; and as for the older children, have they not seen their children going to the school of the Reformed church mission for the last thirty years or so and still not a single convert in the town? So now the Catholic issue is in abeyance; *it* is not worrying the elders; Catholicism, like Protestantism, means merely more shoes or clothes, cakes and coffee Saturday night or on the Saints days which are not otherwise recognized in the native calendar. Nor does the psychological attitude of the youths back from the boarding-schools trouble the elders, as long as the youths are initiated and dance. Zuñi elders are ritualists, not philosophers, pretty much as were our own elders fifty years ago; as long as the young people "go to church" they are not questioned on what they think about it.

Being one of those wholly irrational persons who is not interested in religion for himself, but very much interested in religion for others, during this recent visit to Zuñi, I was beginning to worry, perhaps more than any Zuñi elder, about the town's irreligious tendencies. I was sorry to see two of the paramount priesthoods reduced in numbers—in the rain priesthood of the North or Town chieftainey there are but two members, the Kiakwemosi Klashi has died; and

there are but two members in the war priesthood, Loco Joe, who was initiated in the last Scalp dance as Bow priest elder brother, and Tsawele; Hompikia died last summer (so this winter the Wood society had no ceremonies, it was Hompikia who used to lead them in), and Wayeku died two or three years ago. Tsawele's prestige has diminished since he was charged with witchcraft a few years ago in an attempt to reveal the magical cause of the dysentery from which the townspeople were suffering. After the actual witch had been caught one night trying to lie next to a woman to make her sick, he confessed, showing where he had buried his painted eggs, and he was subsequently banished, but in the public trial in Big plaza he threw suspicion upon his prosecutor, Tsawele, charging him with keeping certain feathers inside his moccasins. As for Loco Joe, now called Joe Crazy Horse, he acts as clown in the Gallup Indian show and more than once in Zuñi I caught some young men laughing at him to themselves. A war priest charged with the crime of all others from which he is counted upon to protect the town, and a war priest, the custodian of the mores, taking to vaudeville and ridiculed by the youth! What are we coming to!

Then there are less unexpected changes going on, to be deplored or not, according to one's point of view. The town is no longer compact; new houses have been built on all its outskirts, houses of dressed stone, instead of stone, mud chinked and plastered, or adobe, and some of the houses have peaked roofs. These changes in building of themselves necessitate changes in the ceremonial life. No longer can the Koyemshi dance from roof to roof singing the song of the mountain sheep, and domiciliary visits by any of the Kachina become less easy.

The first house of stone and with a peaked roof was built about fifteen years ago, by a Cherokee mixed blood married into Zuñi. Two of the recent houses in this style belong to the offspring of Jesús, the Yaqui, to his son by another Yaqui captive, and to his daughter by a Navaho. Another stone house belongs to a woman from Isleta; the woman from Laguna has a stone house. Newcomers of course may have to build houses for themselves and naturally they build on the outskirts; but, practical conditions aside, newcomers tend more readily to innovations than do the old established families. In this connection I note that the single ex-service man is married to an Arapaho.

This marriage was made through boarding-school acquaintanceship. In all the Pueblos the boarding-schools have been a considerable factor in the mixed marriages of recent years; and these have been a factor in breaking down tribal culture, ever since the two Marmon brothers and another white man married into Laguna in the seventies. Mixed marriage and the wage system whereby the youth grow restive against communal service (the Black Rock dam broke the day before I reached Zuñi and the boys complained because they were not being paid for repairing it) and acquire American tastes and habits of expenditure, these two conditions of life are undermining native culture throughout the pueblos. Tourist traffic and vaudeville trips help too. On the wall of Mary's house hung a photograph of the "artists" who had visited Atlantic City—old acquaintances from Acoma, Taos and Zuñi, and some Navaho whom I did not know. All the Pueblo singers had in one way or another broken with their traditions and ceremonial obligations. Some were of mixed blood, but not all. Who knows what germs of cultural disintegration they had brought back from Atlantic City and elsewhere, even from Europe! Gloomy reflections!

Then the day before I was to leave,

Zuñi held a kick-stick race and all such reflections were dissipated into the air, as high as the kick-stick. Here at least was nothing to warrant apprehending that the culture was doomed to disappear, say within fifty years. Spring is the Zuñi season for foot racing, which opens with two ceremonial races, by kiva and by clan. One of these had been held on April 7, on the same day as the last dance of the spring dance season, which was Mosatechiwe, Hopi saint dance. (Although the Hopi have no saints!) The race on April 16 was the first of the general series which would keep up until the Summer Solstice ceremony towards the close of June. This series is more or less in charge of the Sho'wekwe, an informal sort of group whose members know the ritual for the winter gambling games and the spring racing, also a form of gambling. Two Sho'wekwe, sometimes any two men, assemble the race teams of three, four or more members. Sometimes the team are all kinsmen, "like Oscar's bunch." Each team meets in the house of its manager the night before the race, with a Bow priest or a fraternity man to pray and sing and make food offerings to the War gods and to deceased racers. "They give food to the Earth," according to Frank, and, like Deer boy in the familiar Pueblo folktale, they ask the Sun not to beat down on them as they run. "White fellows rest before a race, but we stay up all night," remarked Jakey. During this night sound omens are sought, from birds or from the dead, as they used to be sought in war-time, on the eve of campaign. Sometimes a spy from the other side listens in to these omens; in view of the big bets made on the race advance information is valuable.

About 4:30 P. M. I went to Big plaza to see the betting. Three or four men representing each side advance in two rows to encounter each other in the middle of the plaza. Several carry bundles of goods. These are what have been left over after the racers have made their bets in one of their houses of overnight retreat. These plaza stakes may be matched by bettors at large, and now several men carrying what they wish to put up join the central group. Blanket is matched with blanket and the two tied together, shawl with shawl, silk kerchief with kerchief, belt with belt. All the stakes appear to be wearing apparel, money is bet, but I think privately, and probably only by the younger men. Jakey had planned to bet privately the shirt off his back, an orange silk shirt his sister had just made him, but luckily for him as it turned out, his taker withdrew, and at the close of the day to the satisfaction of all of us he was still wearing his gay apparel, blue velveteen trousers as well as orange colored shirt.

The betting crowd was as quiet as Zuñi crowds ever are; the matching was done quickly and without dispute, no voice was raised, it was a smiling, cheerful party. It took them about an hour, then the piles of goods were left there on the ground and the crowd, on foot and on horseback, about two hundred men, moved across the river by the new bridge to the starting line on the road to the south.

Here we waited for the runners to appear after they had forded the river by the traditional crossing and had said their last prayers. Each team of four men was led single file by their overnight ceremonialist, in this case a Bow priest for one team, and an Ant fraternity man for the other. The leader cast a handful of prayer-meal in front of his team before he left them at the edge of town. With this rite he was "opening the road." The racers continued on, first the Itiwanna or Middle team, a few minutes later the Pathltok or East team,[1] into a stretch of greasewood

[1] Their manager was Has, son of Apah, and they had been in the house used by the Shuma'kwe fraternity. According to Stevenson, this fraternity has racing "medicine."

where they stooped to pray and sprinkle prayer meal. The team scattered, evidently each was praying on his own. Then in single file the runners came over to the starting line, the arms of each folded tightly across his bare chest, as if holding in something. As indeed they are, the powers of four swiftly flying birds—anethlauwa, hawk, shokyapissa, red shoulder hawk, akwatsu'ta, ts'ewia—the same birds, at least some of them, the Hopi mention in their racing song:

> Be racing.
> With joyful words.
> Be racing.
> The abdomen, the back.
> Hawk (Cooper's hawk, etc.)
> Be racing.[2]

These powers for "abdomen and back" have been obtained during the ritual of the preceding night. It is an interesting illustration, by the way, of how the Plains Indian concept of getting power from the Spirits, personal power through personal experience, is transformed in Pueblo circles into power through ritual, for a group.

Our Zuñi racers wear kilts of nondescript cotton or woolen cloth; torso and legs are bare and they are barefoot. "They *have* to be barefoot," *i.e.*, this is a ritual exigency. (The better to attract the atttention and arouse the pity of the Spirits, the Hopi would say.) Itiwan have a white cotton *banda* around the head; Pathltok, one of blue silk. They all happen to be youngish men, from twenty-five to thirty-five, and their hair is short; but the locks on top are gathered together and tied with a string; inside this bunch of hair is concealed an arrow-point, in Pueblo circles ever a protective charm. Protection is needed, for black magic is practiced in these races. Cramps are caused by magic. Ned, one of the returned, English-speaking students, is afraid to race this year because after remarkable success last year he became the victim of magic-induced cramps.

Itiwan arrive first and choose the west side to stand on—the road runs north and south, like the Tanoan race track, by the way. After Pathltok arrive, the two teams face each other and the leader of Itiwan, *i.e.*, the team first to arrive, hands the two kick-sticks to the leader of Pathltok to choose his stick. Now Bow priest elder brother produces some red paint, the ordinary red face-paint, and both sides proceed to paint their stick. The Itiwan leader paints a red band around the center; the Pathltok leader, a red band around the center and a narrower band of red around each end. The sticks are about five inches long, of oak wood, decorticated. As we crowd in to watch and I peer under the big felt hats I notice that the Pathltok leader is blind in one eye and his mouth drawn to one side. He is saying something as he rubs his finger over his stick.

Usually the Bow priest throws the sticks, but this time the two race leaders throw and the race is on. Younger fellows in the crowd run on, whooping the Zuñi war cry—tohálala! tohálala! A man on a white horse takes the lead and will set the course, past Grease Hill, on towards the southern mesas, then towards Towa Yallane, "Corn Mountain," and back to the river ford, a run of about an hour and a quarter, seven or eight miles. The road is soon left and the country is rough going. The stick may not be touched with the hand, nor may it be held between the toes in extricating from crevice or brush.

After the start the house tops begin to fill up with spectators. This is the time bets are made between the men and the women. Frank and I go to the river bank to watch the runners come in. Others have gone out to meet them, so they return with the same whooping

[2] H. R. Voth, "The Oraibi Powamu Ceremony," 152–153. Field Columbian Museum Pub. 61. Anthrop. ser., vol. iii, no. 2, 1901.

crowd they started with. One of the four has dropped out, he will have been picked up by a horseman. The losing team does not finish; they, too, are picked up by their friends on horses. The stick is kicked high, perhaps twenty feet, well over the heads of the crowd, and the kicks I saw at start and finish covered short distances, not more than a hundred feet. The final kick is into the river. But the stick is retrieved and will be placed in an arroyo to be carried away by flood waters, thereby giving speed to the runners. (This information comes in half-breed, Americanized terms. I have no doubt that the sticks are deposited not to make the racers swift but to make swift floods. The Hopi term for racer is Desiring-flooded-arroyo. The Clouds will have seen the fastest runner and will be glad to listen to him, his prayers for rain will have special virtue.)

After crossing, the runners continue on to Big plaza, Frank tells me, run around the pile of bets and return to their house of retreat. Before the goods are moved from the plaza they are sprinkled with prayer-meal and again they are sprinkled in the house of retreat before the winners appropriate them. The people of the house give a big supper. For ritual reasons the runners have been given an emetic.

The losing team, Panch they are called, may reenforce themselves with two new runners. They may also go to two of the paramount rain-priesthoods, the priesthood of the South and the priesthood of the West, for greater power. And they, the Panch, set the date for the next race with their victors, also the course.

I wish I had seen more than the one race and more of that. I have since learned that this spring there have been fourteen more races, including several "bigger" races than the one I saw, involving a longer course and more ritual. Even in the early race I surmise that there were rites I did not hear of, no doubt the leading runner "breathes from" the pile of goods which he circles in the plaza, and no doubt he deposits his kick-stick with prayer-meal the following morning after his hair has been washed.[3] Nothing of importance ever occurs at Zuñi without hair washing.

My calendar-keeping friend has recorded a race every Sunday from April 17 to June 5, *i.e.*, eight Sunday races with another race as a rule during the week, any day from Monday to Thursday. That Sunday should be thus observed indicates that the economic week is now recognized at Zuñi, a very significant change for those who not so long ago "counted their days" wholly by sun or moon. Not that they do not count so still. Three days after the last race on June 6, Sun priest called out that in eight days all were to plant their prayer-sticks for the Summer Solstice ceremony. Nothing of the Augustean calendar in this!

My Zuñi friend has done better by calendar dates than in explaining how the various teams—she mentions five teams and gives the names of forty-eight runners—are selected, nor does she name all the fraternities that made the racers ritualistically fit to run not only to win heavy stakes of material goods but to promote the rainfall which will affect the crops of all the townspeople.

There is still much to learn about the Zuñi kick-stick race, but incomplete as was my ethnographic information when I left the Pueblo, I left with lessened despondency. As long as men bet gaily, risk stone bruise or cactus wound whether for pleasure or for profit, and dread black magic, the spirit of old Zuñi will live on, despite schools, wage system and foreign spouses.

[3] See M. C. Stevenson, "The Zuñi Indians," Twenty-third Annual Report Bureau American Ethnology, pp. 318–328. 1901–2.

SOME MAGNITUDES

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MODERN science is reaching out farther and farther into the distant corners of the macrocosmos and is likewise delving deeper and deeper into the intricate structure of the microcosmos. In this ever-widening frontier of exploration many quantities, large and small, are measured or calculated. Distances are recorded in light years in one branch of science, in Ångström units in another; velocities are measured in kilometers per second and in millimeters per day; while other extremes of the measuring scale are tons and gammas, years and sigmas, atmospheres and dynes and many others more.

To compare some of these significant measurements by converting them into a common scale is the purpose of this paper. In the following tables an attempt is made to collect the most recent data showing the extremes as determined or reasonably calculated by the different branches of science. The task is interesting, for it reveals some rather interesting sidelights.

1. THE DIMENSION OF LENGTH

It is a curious fact that man is just about half-way between the largest and smallest object, for he is 10^{20} times smaller than the Milky Way in which he lives, and 10^{18} times larger than the proton out of which all matter is made. But the indications are that the Milky Way is not the largest, nor the protons the smallest object, and explorations in both directions are still unfinished.

Assuming that we have some conception of the distances existing upon our earth, we find that the diameter of this planet is about three times the air-line distance from New York to San Francisco, while nine times that distance is needed to span the equator. If we travel eighty-seven times between these two cities, we have traveled the distance to our nearest neighbor, the moon. This satellite has a radius extending from New York to Denver and is, with our earth, only a mite in the universe. Nearly twice the distance from earth to moon is needed to arrive at the radius of the sun, hence the moon's orbit around the earth will find ample room to move within the sun. Distances increase rapidly when we measure the remoteness of the sun from us and other planets, yet the diameter of the solar system with its ten thousand million kilometers is but an insignificant fraction of a light year, the latter being nearly 947 times longer. To visualize these spans of space we may calculate the relative distances required for placing a football, nuts, peas and lentils to represent the solar system;—if the nearest star, Sirius, is to be represented by another football, placed at the proper distance, we shall have a demonstration of the reason why we can not observe any planets surrounding other stars, for the size of the solar system is insignificant compared to stellar distances. Yet the multitude of stars which we see on clear nights are but a small fraction of those which make up our galaxy or Milky Way system, the diameter of which has a reach of fifty-thousand light years, or ten times as much as the nearest star cluster. These are objects faintly visible to the eyes, but in the telescopes revealing themselves as accumulations of many stars, likewise at great distances from

each other. The space between our two footballs is large and if all other stars are relatively placed in such spans, our Milky Way system is mostly empty space. Yet beyond this galaxy there are thousands of other galaxies, spaced approximately at forty times their diameters, until we come to the farthest spiral nebula discernible by photographic means at a remoteness of a hundred forty million light years. Yet the end is not yet, for the range of man's calculation, the diameter of the Einstein universe, is fifteen times farther.

Turning in the other direction, we explore the nearness of the microcosmos and follow smaller and smaller particles into the realm of the microscope and the world of cells and nuclei and chromosomes. On the borderland of the visible we come to the domain of colloids and ultramicroscopic particles, and from this aggregation of molecules we pass to single molecules and to atoms. Dissecting the atom into protons and electrons we come to the smallest thing, at present —the nucleus of hydrogen. Magnifying electrons and protons to the size of a football and pea, and placing these at the relative distances from each other to represent the orbits of electrons, we find that these diameters and distances resemble in inverse proportion those of the starry universe and that matter is likewise—relatively empty space.

TABLE 1

MAGNITUDE IN LENGTH

Einstein universe	2,000,000,000 light yrs.	1.9×10^{25} m
Farthest spiral nebula	140,000,000 "	1.3×10^{24} "
Galaxy to galaxy	1,800,000 "	1.7×10^{22} "
Andromeda nebula	900,000 "	8.5×10^{21} "
Milky Way diameter	50,000 "	4.7×10^{20} "
Sirius from sun	8.9 "	8.4×10^{16} "
1 parsec = 3.08×10^{13} km		3.1×10^{16} "
1 light year = 9,462,700,000,000 km.		9.5×10^{15} "
Solar system diameter	10,000,000,000 km.	1×10^{13} "
Neptune from sun	4,400,000,000 km.	4.4×10^{12} "
Earth from sun	149,000,000 km.	1.5×10^{11} "
Sun radius	692,000 km.	6.9×10^{8} "
Moon from earth	384,000 km.	3.8×10^{8} "
Jupiter radius	72,000 km.	7.2×10^{7} "
Earth equator	40,070 km.	4×10^{7} "
Earth radius	6,377 km.	6.4×10^{6} "
N.Y. to San Francisco (highway)	5,230 km.	5.2×10^{6} "
" " " (air-line)	4,451 km.	4.4×10^{6} "
Moon radius	1,740 km.	1.7×10^{6} "
1 kilometer = 1000 m = 1,000,000 mm		10^{3} "
Denver above sea-level	1,638 m	1.6×10^{3} "
Steamer Europa, length	285 m	2.8×10^{2} "
Lowest sound wave	16 m	1.6×10^{1} "
Man, average height	172 cm	1.72 "
1 meter = 1000 mm = 1,000,000 μ = 10^{-3} km		1 "
Highest sound wave	17 mm	1.7×10^{-2} "
1 millimeter = 1000 μ = 1,000,000 mμ = 10^{-6} km		10^{-3} "
Smallest visible particle	50 μ	5×10^{-5} "
Cells of Drosophila	7-25 μ	2.5×10^{-5} "
Nucleus of Drosophila	5-15 μ	1.5×10^{-5} "
Chromosomes of Drosophila	0.2-3 μ	3×10^{-6} "
Coccus bacteria	2 μ	2×10^{-6} "
1 micron (μ) = 1000 mμ = 1,000,000 $\mu\mu$		10^{-6} "
Red blood corpuscle	800 mμ	8×10^{-7} "
Red light wave	770 mμ	7.7×10^{-7} "
Smallest microscopic particle	300 mμ	3×10^{-7} "
Average path of hydrogen	170 mμ	1.7×10^{-7} "
Large colloidal particle	100 mμ	1×10^{-7} "
Shortest ultra-violet wave	13 mμ	1.3×10^{-8} "
Thickness of oilfilm	5 mμ	5×10^{-9} "
Ultramicroscopic particle	4 mμ	4×10^{-9} "
Molecules	0.2 to 5 mμ	5×10^{-9} "
Gas molecule distance	1 mμ	1×10^{-9} "
1 millimicron (mμ) = 1000 micromicrons ($\mu\mu$)		10^{-9} "
Sulfur atoms, distance	900 $\mu\mu$	9×10^{-10} "
Atoms	100-600 $\mu\mu$	6×10^{-10} "
Silver atoms, distance	400 $\mu\mu$	4×10^{-10} "
Soft x-ray wave	136 $\mu\mu$	1.4×10^{-10} "
1 Ångström = 100 $\mu\mu$ = 1000 milliångström (m$\AA$)		10^{-10} "
Electron orbit in hydrogen	53 $\mu\mu$	5.3×10^{-11} "
Hard x-ray wave	19 $\mu\mu$	1.9×10^{-11} "
1 micromicron ($\mu\mu$) = 10 x-units (λ) or m$\AA$ =		10^{-12} "
Shortest gamma ray	2 $\mu\mu$	2×10^{-12} "
Longest cosmic ray	0.6 $\mu\mu$	6×10^{-13} "
Shortest cosmic ray	0.04 $\mu\mu$	4×10^{-14} "
Electron diameter	0.038 $\mu\mu$	3.8×10^{-14} "
Nucleus of gold atom	0.0004 $\mu\mu$	4×10^{-17} "
Nucleus of hydrogen atom	0.00002 $\mu\mu$	2×10^{-18} "

2. THE DIMENSION OF MASS

Perhaps the largest figure calculated by man is the mass of the Einstein universe, namely, an eight with seventy-eight ciphers behind it. Compared with this amount, the galaxy to which our solar system belongs is insignificant, for it has but fifty-five zeros, that is a heptillion times lighter in weight—let the galaxy be an apple, the universe will be the earth. Within this galaxy it is most interesting to find that all stars,

whether giants or dwarfs, have approximately the same mass (although vastly different in size), for their mass varies between 32 and 26 ciphers. The sun, one third million times heavier than the earth, belongs to the smaller stars. The largest planet is 317 times heavier than the earth and our satellite has but one eighty-first part of the earth's mass. Coming down to earth we find the estimated mass of the hydrosphere, that is the oceans, lakes, rivers, snows and ice to be but one six hundredths part of the earth and not quite five hundred times greater than the mass of the atmosphere. Yet the mass of the atmosphere is considerable—and over five times the average mass of an asteroid. The annual fall of meteorites nearly reaches the tonnage of the steamer, *Bremen*, and between this magnitude and the weight of man himself we may enlarge our table *ad libitum*.

Turning to those small quantities which we call "traces" we note with interest that the effective dose of vitamin A is three thousand millionth of a gram, approximately the same amount of magnesium can just be detected by chemical means. Much smaller traces of sodium are detected by the flame test, still smaller amounts of mercaptane are perceptible by its order. Most sensitive for detecting traces, however, is the spectroscope, and this in turn is apparently surpassed by the new magneto-optic method of Allison and others. The masses of colloidal particles and proteins molecules are overlapping. The largest molecule which has been synthesized is maltosazone, which is about twice as heavy as the artificial peptide or protein. The oilfilm must be assumed to be of single molecular thickness, for a minute square of it comes close to the weight of a stearine molecule. Sugar molecules are small in comparison to proteins and fats, yet still heavier than the heaviest atom, uranium. The lightest atom, hydrogen, corresponds to the weight of a nucleus or proton and as such is still eighteen hundred times heavier than the electron. At present the electron is the lightest thing. Protons small and heavy, electrons larger and lighter, may compare with each other like a small and heavy star, as Van Maanen's star or the companion to Sirius, and a very large and light star, as Betelgeuze or Antares.

TABLE 2

MAGNITUDE IN MASS

Einstein universe		8×10^{58} gm
Galaxy (Milky Way system)		2.3×10^{55} "
Large stars		1×10^{34} "
Sun	331,950×earth	1.99×10^{33} "
Small star		1×10^{32} "
Jupiter	317×earth	1.9×10^{29} "
Earth	1.0 earth	5.99×10^{27} "
Mercury	1/25×earth	2.5×10^{25} "
Moon	1/81.56×earth	7.5×10^{24} "
Hydrosphere	1,335,000,000,000 Mill. tons	1.3×10^{24} "
Atmosphere	5,633,000,000 " "	5.6×10^{21} "
Average asteroid	1,000,000,000 " "	1×10^{21} "
Steamship Bremen	51,656 tons	5.2×10^{10} "
Meteorites, annual fall	40,000 "	4×10^{10} "
1 ton = 1000 kg (2205 pounds)		1×10^{6} "
Man, average weight	76 kg (166 pds)	7.5×10^{4} "
1 kilogram (kg)	= 1000 gm (2.2 pds)	1×10^{3} "
1 gram (gm)	= 1000 mg (15.4 grs)	1 "
1 milligram (mg)	= 1000 μg	1×10^{-3} "
1 microgram (μg)	= 1000 γ	1×10^{-6} "
1 gamma (γ)	= 0.000,000,001 gm	1×10^{-9} "
Vitamin A, effective dose	3 γ	3×10^{-9} "
Magnesium by chemical test	2 γ	2×10^{-9} "
Microbalance sensitivity	0.4 γ	4×10^{-10} "
Sodium by flame test	0.07 γ	7×10^{-11} "
Mercaptan by odor	0.002 γ	2×10^{-12} "
Gold particle	(0.000,01 cc cube)	2×10^{-14} "
Colloid particle	(0.000,000,5 cc cube)	2×10^{-18} "
Protein molecule	100,000×H	1×10^{-18} "
Maltoseazone molecule	4,021×H	6.7×10^{-21} "
Octodecapeptide molecule	2,112×H	3.5×10^{-21} "
Oilfilm	(0.000,000,2 cc square)	2×10^{-21} "
Tristearine molecule	890×H	1.5×10^{-22} "
Cane-sugar molecule	342×H	5.7×10^{-22} "
Uranium atom	238×H	4×10^{-22} "
Water molecule	18×H	3×10^{-23} "
Hydrogen atom	1×H	1.663×10^{-24} "
Electron	7/1845 of H	0.01×10^{-28} "

3. THE DIMENSION OF TIME

It is calculated that solar energy comes from a transformation of mass into radiations, that the matter of the sun dwindles in proportion to the light

emitted, hence the sun will slowly diminish its mass. To shrink to half its size we shall have to wait 500 billion years or twenty times longer than for the same process to happen to thorium. Thorium, the longest living member of the radioactive elements, has an average life four times as long as uranium. The Sitter universe, that is the system of galaxies, is assumed to double its size every fourteen thousand million years; this is a comparatively short epoch for such a gigantic undertaking, and this figure will probably be revised in future. The geologic age of the earth approaches close to the time required for doubling the universe, and about one half of this time was spent by the earth in the Proterozoic era and a quarter of it in the Paleozoic era. During the Proterozoic era the sun has traveled four times around the hub of the Milky Way, the solar year being two hundred million years. Since the birth of Christ the newly discovered planet, Pluto, has made over six trips around the sun. Curiously enough, the steam engine, revolutionizing industry, and oxygen, founding modern chemistry, were invented and discovered at about the same time. The foundation of organic chemistry dates but three generations back to the synthesis of urea, and the cornerstone of modern physics is but one generation old with the discovery of radium and x-rays.

Turning to short time intervals we find that the instant which a single image of the moving pictures remains on the screen is but a small fraction of a second but much longer than the fast photographic shutter. The fastest photographic device seems to be the chronotine, an instrument with many photographic lenses and continuous film movement used to take pictures of fast moving machineries which can be speeded up to a series of 10,000 pictures per second. Short-lived are the frequencies of the waves of sound and light. They vary in proportion to the wave-length down to the shortest recorded time for a cosmic ray oscillation. Before reaching this extreme we find the nearly instantaneous birth and death of a radium C′ atom or a thorium C′ atom, likewise the

TABLE 3

MAGNITUDES IN TIME

Sun diminishing one half its mass		1.5×10^{19} sec
Thorium, average life	25,000,000,000 yrs.	7.7×10^{17} "
Uranium, average life	6,300,000,000 "	1.9×10^{17} "
Earth age (He in rocks)	2,000,000,000 "	6×10^{16} "
Universe, doubling in size	1,400,000,000 "	4.3×10^{16} "
Earth, Proterozoic era	850,000,000 "	2.6×10^{16} "
Earth, Paleozoic era	420,000,000 "	1.3×10^{16} "
Sun period in Milky Way	200,000,000 "	6.2×10^{15} "
Earth, Quaternary period	1,500,000 "	4.6×10^{13} "
Ionium, average life	120,000 "	5×10^{12} "
Dawn of history	6,000 "	1.9×10^{11} "
Birth of Christ	1,932 "	6×10^{10} "
Pluto period around sun	282 "	8.7×10^{9} "
Neptune period around sun	164.7 "	5×10^{9} "
Steam engine invented	157 "	4.9×10^{9} "
Oxygen discovered	157 "	4.9×10^{9} "
Urea synthesized	102 "	3.1×10^{9} "
Man, average life	42 "	1.3×10^{9} "
Radium and x-ray discovered	35 "	1×10^{9} "
1 year = 31,536,000 sec.		3.1×10^{7} "
Earth period around sun	365.2 days	3.1×10^{7} "
Mercury period around sun	87.96 "	7.6×10^{6} "
Uranium X^3, average life	35.4 "	3×10^{6} "
Moon period around earth	27.8 "	2.3×10^{6} "
Sun rotation	24.6 "	2×10^{6} "
Radium E, average life	7 "	6×10^{5} "
1 day = 86,400 sec.		8.6×10^{4} "
Earth rotation, 23h. 56m. 4 sec.		8.6×10^{4} "
1 hour = 3,600 sec.		3.6×10^{3} "
Radium A, average life, 4.5 sec.		270 "
1 minute = 60 seconds = 60,000 sigmas		60 "
1 second = 1,000 sigmas (σ)		1 "
Motion-picture image on screen	64 σ	6.4×10^{-2} "
Engine wheel period (1,500 r.p.m.)	40 σ	4×10^{-2} "
Alternating current cycle	10 σ	1×10^{-2} "
Sound vibration (C_3)	4 σ	4×10^{-3} "
Sound vibration (C_4)	2 σ	2×10^{-3} "
Photographic shutter, fastest	1 σ	1×10^{-3} "
1 sigma (σ) = 1,000 millisigma (mσ)		1×10^{-3} "
Chromatine image	100 mσ	1×10^{-4} "
Oscillograph	1 mσ	1×10^{-6} "
Radium C′, average life	1 mσ	1×10^{-6} "
1 millisigma (mσ) = 1,000 microsigma (μσ)		1×10^{-6} "
High frequency cycle	100 μσ	1×10^{-7} "
Radio oscillation	80 μσ	8×10^{-8} "
Lingering period of excited atom	1 μσ	1×10^{-9} "
Thorium C′, average life	1 μσ	1×10^{-9} "
1 microsigma (μσ) = 0.000,000,001 second.		1×10^{-9} "
Yellow light oscillitaion		5×10^{-14} "
Cosmic ray oscillation		1×10^{-22} "

short lingering period of an excited atom, that is, the time required for an excited atom to stay excited.

4. The Dimensions of Velocity

The fastest thing in the universe, and also the most constant one, is light. No matter how long it has traveled or how far it has gone, it speeds on with equal velocity and thereby serves as an astronomical yardstick, the light year. Its fundamental nature makes it also of importance in the subatomic world, where c, the velocity of light, enters into many fundamental equations. Electrons are a close second for honors as racers, for with sufficiently high voltage they can be made to speed on with light. The alpha particles emitted from the radioactive elements have an initial velocity about a hundred times less than light, but they soon tire and stop. Curiously enough, this is approximately the same velocity with which the Sitter universe is expanding or the farthest spiral nebula is receding. Compared with such speeds, the motions within the Milky Way are sluggish, for the sun moves along at the rate of 200 miles per second or seven times as fast as the fastest planet and about seventy times as fast as the slowest planet, Pluto. Neptune's speed around the sun is about equal to the speed of sound in iron and this is but twice as fast as the motion of hydrogen molecules in a container at zero Centigrade. Yet the hydrogen molecules move twice as fast as a rifle bullet leaving its muzzle. The rotation of the earth at the equator, with reference to the sun, is about the same swiftness as that with which oxygen molecules travel at the freezing point of water. The moon travels very leisurely and slowest of all heavenly bodies, with 534 feet per second; this is about one half as slow as sound dashes through the air and nearly twice as fast as the fastest racing car running 254 miles per hour. A nerve impulse compares favorably with the speed of modern railroads and automobiles, while a paper-making machine is conservative and turns out a roll of paper at the rate of fifteen miles an hour.

TABLE 4

Magnitudes in Velocity

Light	186,000	mi. per sec.	2.99×10^{10} cm/sec.
Electrons in cathode rays	.....		10^9 to 10^{10} "
Alpha-particles, initial velocity	20,000	mi. per sec.	3.2×10^9 "
Farthest spiral nebula (recession)	12,300	" ...	2×10^9 "
Sun, around hub of Milky Way	200	" ...	3×10^7 "
Mercury around sun	29.7	" ...	4.78×10^6 "
Earth around sun	18.33	" ...	2.95×10^6 "
Neptune around sun	3.37	" ...	5.43×10^5 "
Sound in iron	3.1	" ...	5×10^5 "
Hydrogen molecules at 0° C.	1.11	" ...	1.8×10^5 "
Sound in water	0.9	" ...	1.46×10^5 "
Rifle bullet in air	1,970	ft. per sec.	6×10^4 "
Nitrogen molecules at 0° C.	1,630	" ...	4.97×10^4 "
Earth rotation at equator	1,525	" ...	4.65×10^4 "
Oxygen molecules at 0° C.	1,525	" ...	4.65×10^4 "
Sound in air	1,089	" ...	3.32×10^4 "
Moon around earth	534	" ...	1.63×10^4 "
Speed car on racing beach	370	" ...	1.14×10^4 "
Wind at 100 miles p.hr.	150	" ...	4.57×10^3 "
Nerve impulse	128	" ...	3.9×10^3 "
60 miles per hour	88	" ...	2.68×10^3 "
20 miles per hour	29.2	" ...	9×10^2 "
Paper-making machine	16.6	" ...	5×10^2 "
1 centimeter per second	.....		1 "
Crystal growth (picric acid)	14.3	mm per sec.	1.43 "
Gas diffusion (H into O)	6.9	" ...	0.69 "
Fastest plant growth	0.03	" ...	3×10^{-3} "
Crystal growth (o-phosphoric acid)	0.018	" ...	1.8×10^{-3} "
Growth of beard	0.0001	mm per sec.	1×10^{-5} "
Diffusion of gold into lead	0.002	mm per day	4.6×10^{-9} "

Turning to slow motions we find that picric acid is among the fastest growing crystals, it grows about one eighth of an inch in two seconds; about half as fast is the diffusion of hydrogen into oxygen. The fastest growing water plant is three hundred times as swift as the growing beard of a freshly shaved man. Among the slowest of the slow is the speed with which gold atoms diffuse into lead. No attempt has been made to evaluate the slowest motion of all, the displacement of stars in the line of sight, which naturally is only apparent and represents not the true notion. In astronomy we find the fastest and the slowest motions.

5. The Dimension of Temperature

Compared with other magnitudes, the range from one extreme to the other is very small in theoretical and practical temperature. The relations seem simpler and can be grasped more readily: thus from the hottest climate in Tripoli or Death Valley to the coldest climate in Alaska or Northern Siberia, there is but a difference of 110° C.; while between the greatest heat artificially produced and the greatest cold achieved experimentally, there is about 5,700° C. difference; but theoretically the temperature in the stellar interior reaches forty million degrees, which still leaves the entire range of temperatures within seven ciphers. From the hottest stellar interior there is a gradual drop in temperature as we reach the stellar surface; this drop is so large that even in the hottest stars, Class B type, the surface temperature is but one two-thousandth, or 23,000° C., while the coldest visible stars, Class M type, have 3,000° C. at their surface and thus come within the range of temperatures produced artificially upon our earth. The sun surface is about three times hotter than the oxy-hydrogen blowpipe; this temperature can be closely approached on earth in the focus of a system of nineteen lenses, a sun or solar furnace. The atomic hydrogen torch is not very far behind and is followed closely by the marvelous induction furnace which heats conductors as high as they can stand, usually up to their melting point. Besides graphite, tungsten has the highest melting point of any element. Of organic compounds the highest melting point has the hydrocarbon rubrene. Within the narrow range of about five hundred degrees are the melting and boiling points of all organic compounds. Climates hotter or colder may have been reported, but either inaccurate thermometers or improper methods have been used and at present the most reliable figures are 136.4° F. for the hottest and −87° F. for the coldest climatic temperature. This is far above the temperature of liquid air or liquid hydrogen. Coldness is harder to produce than

TABLE 5

Magnitude of Temperature

Stellar interior	72,000,000° F.	40,000,000° C.
Stellar surface (B star)	41,000° F.	23,000° C.
Solar surface (G star)	10,800° F.	6,000° C.
Sun furnace (focus of 19 lenses)	10,000° F.	5,500° C.
Atomic hydrogen torch	7,600° F.	4,200° C.
Induction furnace (conductors)	7,200° F.	4,000° C.
Electric arc in vacuum	5,400° F.	3,000° C.
Stellar surface (M star)	5,400° F.	3,000° C.
Tungsten, melting point	5,350° F.	2,970° C.
Oxy-hydrogen torch	3,600° F.	2,000° C.
Gas burner	3,090° F.	1,700° C.
Rubrene, melting point	932° F.	501° C.
Water, boiling point	212° F.	100° C.
Hottest climate (Tripoli)	136.4° F.	58° C.
(Death Valley)	134.1° F.	56.8° C.
Man, body temperature	98.6° F.	37° C.
Ocean water (La Jolla)	78.4° F.	25.7° C.
Water, freezing point	32° F.	0° C.
Mercury, freezing point	−37.8° F.	−38.8° C.
Coldest climate (Alaska)	−82° F.	−63.3° C.
(Northern Siberia)	−87° F.	−66.1° C.
Liquid air	−319° F.	−195° C.
Interstellar space	−454° F.	−270° C.
Hydrogen freezes	−458° F.	−272.2° C.
Lowest experimental temperature	(0.75° A.)	−272.38° C.
Absolute zero	(0° A.)	−273.13° C.

(1° F. − 0.5556° C. and 1° C. − 1.8° F.)

hotness. It takes more energy to cool than to warm, and scientific progress is difficult, for each tenth of a degree is an achievement as we approach absolute zero. Interstellar space is about three degrees above absolute zero and experimental methods have reached temperatures within three fourths of a degree of absolute zero.

Conclusions

In making this short inventory of magnitudes but a few physical properties have been selected. It is found that the range of magnitudes varies, it is greatest in mass and smallest in temperature.

Range of Magnitudes

(1)	Length	10^{28} m
(2)	Mass	10^{106} gm
(3)	Time	10^{41} sec.
(4)	Velocity	10^{20} cm/sec.
(5)	Temperature	10^{7} °C.

Naturally many other properties, such as calories, pressure, volume, density, electric charge, magnetic moment, etc., could have been selected in this inquiry into the largest and smallest and would have offered a similar interesting excursion to the frontiers of science—interesting to those who can realize the human effort necessary for discovering these figures.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

FLYING THROUGH THE ANCIENT NEAR EAST

By CHARLES BREASTED

ORIENTAL INSTITUTE, UNIVERSITY OF CHICAGO

THOSE of you who have traveled in the near Orient know that to-day between England and India and South Africa, between Holland and Java, between France and Cochinchina, and between Germany and Russia and Persia there are in operation regular passenger and mail air services. Amateur solo flyers over these routes may break into the headlines for apparently remarkable exploits. But quietly, week after week, through blazing desert heat or across snow-capped ranges, through dust storms sometimes sixteen thousand feet deep, and over tropic seas, the pilots of these various airlines carry on over their long air trails. Only when you have crawled across these dreary stretches by caravan or motor car or even by ship can you fully appreciate the vast amount of time and effort saved by air travel.

Before sharing with you a flight made through the Near East for the especial purpose of securing a motion-picture record of our field work, whence I have just returned, let me explain briefly the nature of the Oriental Institute of the University of Chicago. With twelve field expeditions scattered through Egypt, Palestine, Syria, Turkey, Iraq and Persia, it is to-day the largest archeological research organization in the world. It was created in 1919 by Dr. James H. Breasted, its director, with funds appropriated by Mr. John D. Rockefeller, Jr., and its subsequent expansion has been due both to him and to two of the Rockefeller boards, as well as to various individual supporters. The institute's beautiful new headquarters building on the quadrangles of the University of Chicago constitutes the first laboratory ever set up for the study of the rise of man from remotest savagery to the conquest of civilization. The main floor of this headquarters is given over to a group of exhibition halls, where in less than an hour you may gain a bird's-eye view of the whole career of man in terms of man's own handiwork, both practical and artistic.

The Near East—where civilization first arose—is to-day literally a great warehouse of buried ancient cities and towns filled with the paraphernalia of man's daily existence thousands of years ago—equipment long since "written off" by the inexorable wear and tear of history. These ancient cities are now silent mounds, representing layer upon layer of different periods and civilizations. Armies conquered a place, burned and ruined it, and presently either the victors or what remained of the original inhabitants would level off the ruins and construct upon them a new city. Or merely the disintegration wrought by time and weather, as any present-day oriental town will bear witness, would cause buildings to tumble in, necessitating the creation of new ones upon the old. Thus, by what we call the process of "urban stratification," there grew up city mounds, great "layer cakes" of different civilizations and periods which the Oriental Institute and other scientific archeological organizations are systematically excavating. From the ma-

terials thus unearthed we are able to reconstruct not only the buildings and furnishings of a given period, but even the life which once pulsed through the ancient streets—how kings ruled, armies fought, ordinary folk tilled their fields, bartered and traded, married, begat families and at length died and were buried. Along a far-flung front of over thirty-five hundred miles, from Upper Egypt on the south, Turkey on the north to Persia on the east, the expeditions of the Oriental Institute are meticulously, painstakingly gathering, excavating, recording, exploring; and out of this new, synthetic attack upon the story of mankind, which enlists the assistance of geologists, paleontologists, ethnologists, anthropologists, botanists, medical men, chemists, archeologists, philologists and historians, it is hoped there will grow *the* authoritative, interpretative history of civilization.

Because the field work of this widespread organization had never been recorded in motion pictures, your speaker persuaded Dr. Breasted, his chief, to lend his services toward the production of a talking picture to be called "The New Past," of which Part I should contain a synopsis of the rise and development of civilization, and Part II a vivid survey of the Oriental Institute's leading field expeditions in the Near East. Part I was completed at Chicago last February with notable success; but the completion of Part II was a much more ambitious undertaking and became the major business of your speaker's annual visit to our field projects.

In every department of its work the Oriental Institute has always tried to avail itself of the latest developments of science, from sound pictures and aviation to the delicate technique of modern excavation and recording. Finding upon my arrival in Cairo last March that quite by chance the well-known English pilot, Captain Gordon P. Olley, chief charter pilot of the Imperial Airways, Limited, was in Cairo with an Avro Ten—a trimotored Fokker type 10-passenger monoplane—I welcomed the opportunity of chartering this machine with an additional crew of two, consisting of radio operator and assistant pilot, for an air visit to our widely scattered expeditions. The renown of Captain Olley among his colleagues arises from a brilliant war record and subsequent flying now totaling well over ten thousand hours—more than eighteen months of his life—in the air! His skill and trustworthiness is attested by his having so frequently carried across Europe the Prince of Wales, the King of the Belgians and other notables whose lives belong to their people.

Accompanied by Mr. Reed Haythorne, our cameraman especially dispatched from America, we took off at dawn on March 23rd from Heliopolis airdrome outside Cairo and headed northeast for Biblical Gaza in Palestine, where we refuelled before continuing on across the Dead Sea, Transjordania and the nearly six hundred miles of desert beyond which lies Baghdad. In the middle of this desert lies a tiny Beau-Geste-like fortress guarding the ancient Rutbah Wells—a place no larger than a pin point on the map, yet by means of Marconi's remarkable new direction finder, a haven for all the air services. Behind its barbed wire entanglements and machine gun emplacement you may eat an excellent meal while your plane is being refuelled. Every drop of gasoline and morsel of food has been hauled across the desert from Damascus or Baghdad by motor convoy.

From Rutbah we flew on to Baghdad through a fiendish dust storm in which visibility was nil and progress was possible only by constantly establishing our position through radio. Captain Olley, who had never before flown this route, literally bisected the Baghdad airdrome,

and brought us safely down. After a sleepless, choking night, the dust settled as suddenly as it arose, and we were able to record in "movies" the work of our Iraq Expedition, stationed about 50 miles out in the barren plain northeast of Baghdad, where we are excavating two large ancient Babylonian cities, the latest "layers" of which date from 2500 B. C., or some 4,500 years ago.

Thence we pushed on to Basra, the great port of Iraq on the Persian Gulf, and on to Bushire, our airport of entry into Persia. The dust had risen again and we felt our way along the Persian coast in a twilight through which, after Bushire, we had to climb to 12,000 feet before we found the clear sunlight. The silver-tan peaks of three great mountain ranges stood out in the late sun, like islands in a vague sea of gray-brown dust; and here and there the islands were covered with snow. Sailing along in the even, cold upper air we came at length to Shiraz, which lies in a plain over five thousand feet above sea-level, and thence by car continued to Persepolis, the most magnificent site of the ancient world, with the single exception of the Acropolis at Athens.

Persepolis, the capital of the Persian Empire built by Darius the Great about 500 B. C. and destroyed by Alexander the Great in 331 B. C., stands at the base of a black mountain on a great terrace built of gigantic blocks of stones taller than a man, and surveys a vast plain encircled by mountains. Here ruled the emperors of ancient Persia—and here to-day the Oriental Institute is excavating and restoring this place of transient grandeur. Our expedition headquarters is the reconstructed harem of Darius! Needless to say, our cinema record of Persepolis—the first one ever made on standard size film—is of remarkable interest.

From Persepolis we drove back to Shiraz (a distance of some 40 miles) and once more enplaned for Bushire and Baghdad, where we were again delayed by a dust storm—the one in which Colonel Regnier, president of the League of Nations Frontiers Commission, crashed with pilot and companion as they were en route from Damascus to Baghdad to consider the realignment of the frontiers of Kurdistan, where at the moment the mountaineers are in a state of war. As we took off from Baghdad early on the morning of March 30, we watched the funeral cortege bringing the bodies to two waiting Royal Air Force bombers which flew them to Damascus.

After recording the institute's work at Khorsabad, some eighteen miles northeast from Mosul, where we are excavating the palace and city of King Sargon II, once ruler of Assyria, from whose palace the Institute secured the great winged stone bull now installed in its exhibition halls here at the Chicago headquarters, we continued on, southwestward across the desert, *via* Rutbah to the shores of the Lake of Galilee, whence by car we achieved our expedition excavating the Mound of Megiddo, which guards the pass leading through the Carmel Range of hills. Every army of ancient times, marching from Palestine to Egypt or the reverse, had to use this pass, and even in the late war, Lord Allenby sent through it in a single night his 20,000 cavalry. It was natural that in very early times so strategic a point should be occupied by a town which gradually grew to large proportions. The Institute is peeling off stratum after stratum of different occupations, and at present has laid bare the city of the time of Solomon (about 950 B. C.), where you may walk through the stables once occupied by his blooded horses which he traded with neighboring countries. Here we made a fascinating picture record, including that of a newly discovered tomb deep in the native rock.

From Megiddo we returned to the Lake of Galilee and took off again, circling over Nazareth and Haifa, and above Megiddo, photographing as we went, and southward to Jerusalem, and at length back over the Suez Canal to Cairo, where we added to our ground record of Luxor and Memphis air views of the great Pyramids, the step Pyramid and the ancient cemetery of Memphis, before coming down once more at Heliopolis airdrome.

On a magic carpet, albeit to the roar of three motors, we had circled the major portion of the ancient Near East, had secured some twelve thousand feet of unique motion-picture record, and had in the face of every sort of obstacle, returned to our starting point on absolutely scheduled time. I can conceive of the day—it may even be upon us now—when a far-flung archeological organization will find its own aircraft indispensable to the maximum efficiency of its field work.

In conclusion, for those of you who are asking what disposition we expect to make of this motion-picture record, let me say that we shall select from it the material necessary for completing "The New Past," to the accompaniment of Dr. Breasted's voice describing what you see. We shall also make from it at least two other pictures, both in sound. "The New Past" should be ready for release by March, 1933, and possibly also most of the shorter pictures. While "The New Past" in its original version is being prepared primarily for audiences in educational institutions—colleges, schools and other groups—it is not unlikely that a more popular version will be prepared for wider showing.

ECHOES GIVE OCEAN DEPTHS[1]

By Dr. HERBERT GROVE DORSEY

PRINCIPAL ELECTRICAL ENGINEER, U. S. COAST AND GEODETIC SURVEY

ECHOES, which are made by sounds reflected back to you, are heard on all sides and by everybody; you are so used to hearing them that they are seldom noticed unless the echo is heard at a considerable time interval after the sound is produced. In a room with bare walls we hear the echoes so quickly that the result is called reverberation and considerable money is spent preventing reverberation in a broadcasting studio. Being so common, you would scarcely believe that echoes are useful and can save time and money as well as promote safety at sea.

Safety at sea was on everybody's lips after the tragic disaster of the *Titanic*, twenty years ago. How could the sea be made safer; how could we know when icebergs might be near enough to cause danger? Many minds were turned towards a solution of this problem and one mind, at least, thought of the possibility of receiving a submarine echo from an iceberg by a sound produced in water. The experiment was actually tried by Professor Reginald A. Fessenden, and whether he received echoes from the iceberg seems to be omitted from the record. But he did succeed in getting echoes from the bottom of the ocean, which was perhaps more important, for the sea always has a bottom, while you can't find icebergs on every little summer's outing at sea.

While you get echoes so easily in air you will be surprised to know that you can hear them more easily in water, for

[1] Publication approved by the Director of the Coast and Geodetic Survey of the U. S. Department of Commerce.

sound travels better in water than in air, travels faster and farther. It passes through water so much faster, about four and one half times, that it is not easy to measure shallow ocean depths by the echo method because the time interval is so short. In water, sound travels about 4,800 feet per second and since a fathom is six feet the sound will go down and back through a depth of 400 fathoms in one second, or through a depth of one fathom in one four hundredth of a second, which is only two and one half thousandths of a second. We think of a stop watch measuring to a fifth of a second as being very fast. It used to be the last word in timing horse races, but in this day and age, when we hear so much about split seconds, it is entirely too long even for races!

Measuring ocean depths is probably as old as the art of sailing ships, for Herodotus some four hundred years B. C. mentions putting grease on the bottom of the sinker to bring up a sample of the bottom. No practical improvements were made for twenty-three centuries, until Lord Kelvin utilized the idea of pressure tubes, which was still further improved in accuracy by Commander G. T. Rude, of the Coast and Geodetic Survey. While Fessenden's method would work in deep water, it was cumbersome, requiring a skilled observer to use head phones and listen intently to distinguish the difference between echoes and water noises, and it was absolutely impossible to measure shallow depths with it. Ship captains were not interested in it and nothing was done commercially. Although several attempts were made to produce something better, Fessenden's model lay practically dormant until 1922.

At that time the Submarine Signal Company put two of its engineers on the problem, R. L. Williams and myself. Williams was a mechanical engineer, unfamiliar with radio, while I had just completed experiments on the radio loud speaker, now so extensively used. Naturally, we attacked the problem along different lines, he holding to mechanical devices while I tried to tune everything and amplify the weak echoes. This desire to amplify was ridiculed because it was thought impracticable to attempt to use amplifying tubes on a ship unless under the constant supervision of the wireless operator. Of course amplification helped and proved to be the only way to success. On an experimental trip on the ship *Calamares,* the captain asked me if I could measure shallow depths and said, "When you can measure six to ten fathoms, you will be doing something!" It was not long after that when I had a visual method worked out in the following manner.

In one part of the equipment, called the indicator, there is a small motor with a governor which, through a system of gears, rotates a black disc four times per second. Attached to the back side of the disc is a tiny neon tube, just a small edition of the same as is used in advertising signs, and when it is illuminated its red light shines through a slot in the disc, but it is lighted only now and then. In front of the disc is a sheet of glass on which is painted a circular scale marked in fathoms from zero to 100. Every time the neon tube passes the zero point of the scale, an electric current passes through a sounder bolted to the bottom of the ship and a sound is produced as a short whistle blast, two octaves above middle C, like this: (Illustrate by whistling the short blasts for two seconds). Only these sounds pass into the water; no wire is lowered, nothing is dropped, no connection with the bottom is made. The sounds themselves do the work by being reflected from the bottom of the ocean as echoes.

As the echoes return to the ship they are "heard" by a receiver of submarine sounds, or electric ear as it might be called, and an amplifier using thermionic tubes, similar to those by which you are

now hearing my voice, increases the loudness of the echoes so that the electrical energy will cause the tiny neon tube to make a single brilliant instantaneous red flash of light as the tube whirls around with the disc. This flash will shine through the glass, opposite some mark on the scale, six fathoms, for example, if that happens to be the depth of water through which the ship is passing. Four times a second the red light flashes at six fathoms, thus measuring a time interval of only fifteen thousandths of a second, and you read the depth as easily as you read time on a clock. Now, as the ship travels through deeper water, the red flashes will occur at later intervals, making the indications move along the scale to show increasing depths. In going from deep water to shallow, of course the red flashes will follow the scale backwards just as well as forwards. If the depth increases to more than a hundred fathoms a handle is turned shifting to a slower speed and another scale, so that, while the indications come less often, the depths can be measured to 3,000 fathoms or more, nearly 3½ miles of water.

Since the instrument measures fathoms, I named it fathometer, and as such the fathometer is now used on hundreds of ships measuring fathoms whenever the captain wishes. In former days, he would have to slow up the ship, if the water were shallow, or stop if it were deep, while now he presses a button, the fathometer starts and after a few readings to assure himself that he has plenty of water he pushes another button. It is all finished in a few seconds, even though the depth be a thousand fathoms! By the method of lowering a wire to measure this depth, the ship must be stopped at least a half hour, while now it can proceed at full speed, twenty to thirty knots, and in any kind of weather, day or night. With the fathometer right in the pilot house, the skipper has no anxiety about the depth.

In the United States Coast and Geodetic Survey, we are using fathometers on thirteen ships to chart the ocean depths. Since we can run the ships at full speed, we can get many more soundings than formerly, not only doubling the speed of hydrographic surveying, but getting so many soundings that we can make charts better and faster at lower costs than by the former, slower methods. With a ship speed of ten knots and four soundings per second, the depth is obtained about every four feet, so that even slight changes in ridges and valleys are now found which might not have been noticed by old methods. Every so often our ships are stopped and very careful measurements made with a wire and lead sinker, and serial temperatures of the water are taken so as to get an accurate correction on the fathometer, to keep it calibrated as a precision instrument. A little grab bucket at the end of the wire brings up a sample of the bottom. The fathometer can not do that, but as one watches the red flashes he can get some idea of the bottom, for the echoes are less regular from a rocky bottom than from a smooth one.

Since greater details are given in our charts, navigators are finding them much more useful than just mere road maps of directions at sea. The bottom is seldom flat for any considerable area and, if a navigator is lost in a fog, he can keep his fathometer running a few minutes, mark the indications on a piece of thin paper and by moving this around over the chart, keeping it parallel with his course, he will find some line on which his soundings will agree with those of the chart, locating not only his position and direction of travel, but giving also his speed. So vivid are the fathometer indications when steaming over rapidly changing depths that it is almost like seeing the bottom rise and fall as do the hills and valleys by the road side as you ride along in an automobile. The configuration of the ocean bottom is not unlike that of our land surfaces; some-

times changing so rapidly that it almost resembles cliffs, palisades and canyons. I have measured slopes in the China Sea and in the Pacific near San Francisco, which have about the same average grade as the mountains near the coast, while the ocean bed to the east of north Florida, while having a gentle slope towards Spain, is as flat as the state of Florida itself.

What do you suppose the fish think think about all this whistling? Well, by watching them, in clear water, when the fathometer is first started, they appear frightened and rush away from the sound; but after ten or fifteen seconds they get used to it and swim around the ship as usual. Dog fish might try to bark at it—who knows? Herodotus probably knew about echoes as well as about grease on the bottom of the sinker, but I would like to watch his reaction to a fathometer while sailing the Aegean Sea.

FEEDING THE GROWING POPULATION

By Dr. WILLIAM CROCKER

DIRECTOR, BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH, INC., YONKERS, N. Y.

In 1798, Malthus, an English economist, wrote his famous essay on "The Principle of Population as it Affects the Future Improvement of Society." He stated that at all times population has tended to overrun subsistence and that, while subsistence increased in arithmetical progression, population increased in geometrical ratio. Consequently, there could be no permanent amelioration of the lot of the lower classes, for while redistribution of wealth might bring them plenty for a time, population would soon overtake subsistence and they would again be kept in check by starvation or vice, unless checked by self-restraint. Malthus put this theory forth in part to answer what he believed to be two erroneous theories of his day. Certain statesmen, like Pitt, held that the increase in population was an unqualified advantage and socialists were advocating redistribution of wealth.

I do not want to dispute Malthus' theory as a theory. If population were to continue to increase with a constant and high geometric ratio, some time in the future food would limit population. I do want to take exception to the Neo-Malthusians with their alarmists' ideas of such a disaster being imminent. In spite of these alarmists' ideas, we have more food to-day per population than we ever had before. To-day it is not a question of how to raise enough food for our population, but what we shall do with the great excess we produce. Also, never before were there such great possibilities of future increases in food production. We literally have food to burn and will continue to have for some time yet, unless we curtail production, and for a long time yet, unless we curtail threatened increases in production. One and one third centuries after Malthus' pronouncement that population always tends to overrun subsistence, the dictum has been quite reversed, increase in food production has overtaken increase in population, and the possibilities of enormous future increases in food production are just beginning to be realized.

Why the present-day reversal in the Malthusian conception? It is largely due to three changes that have occurred since Malthus' time and that could not, at that time, be foreseen: (1) The fall in the ratio of population increase amongst more highly developed nations; (2) invention of farm machinery; and

(3) research in plant and animal sciences, or agriculture.

Because of lack of time and the great importance of the second and third points, the first point must be passed over with a few illustrations. At the present rate, the populations of Cuba and Porto Rico are doubling once in 25 years and that of the United States, with limited immigration but large foreign population, once in 45 or 50 years, while France is showing little increase in population. The great decline in birth rate in the large cities of Germany and the United States in 1931, as compared with 1930, shows how economic stress and not man's power to produce food is likely to reduce the ratio of increase of population in more highly developed countries. Desire of ease amongst the middle and upper classes of such nations has a similar effect.

Invention and development of effective farm machinery during the last 80 or 90 years has reduced greatly the amount of manual labor necessary for producing man's food, and the resulting ease in food production has led to a growing surplus. The United States and the British Isles have furnished most of the inventors in this field. Amongst these should be mentioned Cyrus Hall McCormick, inventor of the reaper, and John H. Appleby, inventor of the twine knotter that made the self-binder possible. With the grain sickle, it required five men one day to cut and bind one acre of wheat. With the cradle, two men would accomplish as much. With the reaper, one man could cut and bind two acres a day. With the binder ten acres was a day's work for one man, and finally with the combine one man could cut and thresh ten acres a day. From the sickle to the self-binder man has increased his efficiency in harvesting his breadstuffs fifty-fold. From the crooked stick to the modern gang plows pulled by tractors similar advances have been made in breaking the soil. A like advance has been made in cultivation of crops from the hand hoe to the four-row cultivator drawn by a tractor at twice the speed of a horse cultivator.

These examples are typical of what invention of farm machinery has done in increasing man's labor efficiency in food production. In 1870, 90 per cent. of the population of the United States was on farms; in 1929, 22.9 per cent. Farm machinery has released about two thirds of the population of the United States for factory production of necessities, such as clothing and furniture, and for the making of luxuries—bathrooms, electric refrigerators, automobiles, etc. Before the invention of farm machinery, man used nearly all his time to produce his food and other mere necessities, and shortage of food and even famine were common. Now his granaries are always overflowing.

In 1900, and for some years afterwards, nearly all power on the farm and for city drayage was horse power, with hay and grain as its source. With motorization of farm work and city drayage, petroleum displaced hay and grain as a source of power and released much food for direct use by man or for indirect use through dairy, egg and meat production. If the horse had all his old jobs back in the United States to-day, corn and hay would be scarce and high-priced. Malthus, of course, could not foresee this releasal of food which was to occur more than a century after he wrote his essay. When man converts vegetable materials into animal food materials, such as milk, butter, eggs and meats, he incurs a great loss in nutritive value and energy. If the direful day prophesied by Malthus approaches, man can push back the day of starvation by turning more and more to a vegetable diet.

Let us turn to the effect of agricultural research on food production. Much of the time of agricultural scientists has been devoted to working out methods of controlling diseases and pests of man's food plants and animals partly due to the fact that ever-increasing exchanges of plants and animals have distributed these diseases and pests to all regions of the earth and partly due to the ravages of pests within their native haunts. The efforts of the scientists in this direction have enabled man merely to hold his own against the detrimental agents to food production. Let us consider a few examples.

Just prior to 1900 a leafhopper was introduced into Hawaii from the South Sea Islands that threatened to completely wipe out cane production in the Hawaiian Islands. Several years of study and work by entomologists led to the introduction from the native home of the leafhopper insect pests that completely control it. Some years ago a disease of cabbage—cabbage yellows—threatened to wipe out the cabbage industry. Dr. L. R. Jones, of Wisconsin, saw a 20-acre field in which only a few heads were perfect and without disease. He said, "These plants are probably resistant to yellows." He grew seeds from these, and through many years of selection and intensive study now has resistant forms that grow perfectly in diseased soil. Through extensive, careful experimentation the cause, manner of transmission and remedies for Texas fever of cattle and cholera of hogs have been worked out. These are four of many such conquests scientific workers have waged successfully against pests and diseases that have threatened man's food supply. The background of scientific information and principles established in control of diseases and pests insure that future threats to man's food supply will be handled with even greater facility. Scientific men have not merely met and conquered pest and disease threats to man's food supply, but they have made marvelous advances in the knowledge of plant and animal nutrition and breeding that add greatly to food-producing possibilities.

In 1840, Liebig, the great German chemist, put forth his theory of soil fertility. This stimulated Sir John Lawes, of England, to organize the first and most renowned agricultural experiment station, the Rothamsted Station at Harpenden, England. This tested and corrected Liebig's theories and established many of the laws of soil fertility. Basic knowledge in nutrition of plants and soil fertility has accumulated rapidly up to the present day and established a firm basis for increased crop yield. Let us observe three discoveries on soil fertility and plant nutrition within the present century that have led to great increases in food production. In the northwestern United States it was discovered that the soil was deficient in sulphur. By adding sulphur compounds to the soil, alfalfa yields could be raised as much as five-fold. The discovery that pineapples grown in various soils of Hawaii were starving for iron and that the iron had to be fed through the leaves as an iron sulphate spray made possible the development of the large pineapple industry of Hawaii. Recently, non-productive peat soils of Holland and the United States have been found to be deficient in copper. By addition of copper the soils become highly productive vegetable lands. The great development of knowledge in animal nutrition, though it came later, is also important in increasing production of animal materials for human foods.

Breeding and selection has done much to increase food production by plants and animals. Dr. William Saunders and his son, Dr. Charles Saunders, by fifteen years of breeding and selection of wheat, produced Marquis wheat, the

present spring wheat of western Canada. This wheat has about six days' shorter growing season that the Red Fife, which it displaced. It thereby misses fall frosts, which results in an increase in yield of nearly 30 per cent. Java's cane-breeding work, stretching over a period of more than 20 years, has produced the new P.O.J. canes that, under identical cultivation methods, produce three times as much sugar per acre as any of the canes entering into the crosses. More than fifteen tons of sugar per acre per crop have been produced. With these new canes and with improved methods of cultivation now known, two small islands, Cuba and Java, besides growing much other food for their people, can produce with profit all the sugar the world can eat at two cents a pound at the mills.

The extensive and thorough research in plant and animal sciences has placed in man's hand tools for an enormous increase in food production. Still more important, it has uncovered many facts and established many principles as a basis for future discoveries that may lead to increases in food production not dreamed of to-day. Besides all this, it must be remembered that the tropics, with tremendous possibilities for growing food, have been largely untouched as a region for food production. In closing it may be said that for a long time to come man's problem will not be as Malthus thought, production of enough food for his subsistence, but rather how to readjust his distribution system so that the whole population of the earth can benefit by the great power man has to produce food and other commodities.

SEEING THINGS AT A DISTANCE

By Commander C. L. GARNER
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PERHAPS all of you have climbed to the top of some high mountain, or, if not, to the top of a tall building or monument, and from these high places have seen objects at distances much farther than you thought it possible to see. This would be particularly true if you were so fortunate as to have fair weather and a clear atmosphere at the same time. Many of us are denied the experience and pleasure of looking out into open spaces, such as afforded those sailing high seas—of viewing the open expanses of water from a seaside cottage, or of scaling some high mountain—more than about once each year or perhaps every blue moon. On such occasions it is probable that some of these questions came to your mind. How far is the horizon?—that ship?—that mountain peak?— town or monument? How high must it be in order to be seen that far? And, finally, How far after all do our eyes reach on this earth of ours?

The man on reconnaissance for triangulation, and the triangulator himself, must be familiar with these facts and the importance they bear to their work in order to plan and extend arcs of triangulation about the country without serious interruption or undue expense. Triangulation is the means employed by all nations of the world for the extension of large scale surveys around their boundaries and across their interiors for the control or coordination of all classes of public and private surveying activities. One of the prerequisites in the selection of triangulation stations is that each station must see practically all other stations adjacent to it in order that the observer may later occupy these same

points with a theodolite and accurately measure the angular values between the stations around the horizon. This work extends into all sections of the country, and in mountainous regions it is natural that many of the stations should be on high peaks and that many long lines between these stations would occur. Moreover, in the early days it was essential that the work progress across country as rapidly as reasonable economy would allow, as otherwise our mapping program would have proceeded at a much slower rate than the snail's pace it now has.

In the United States the longest line over which instrumental observations have been made at both ends of the line is between Mt. Shasta and Mt. St. Helena in California, a distance of 192 miles. Another long line was between Mt. Ellen, Utah, and Uncompahgre Peak, Colorado, a distance of 183 miles. In both cases the observations were made on heliotropes having 12-inch square mirrors.

In the triangulation across the Mediterranean Sea between Spain and Africa, the length of the longest line used was 168 miles, while in the great trigonometric survey of India the longest side of any of the main triangles was 63 miles. On the other hand, a large number of Himalayan peaks were observed from occupied triangulation stations of the Indian survey and the distances to many of these peaks exceeded 200 miles. In the latter work the pointings of the instrument were on the visible outlines of the peaks against the sky and no observations were made from the mountains themselves. It is believed that both lamps and heliotropes have been used in the observations outside of the United States.

With the recent improvement of the electrical signal lamp observations for the most important triangulation in this country are made almost entirely at night. This lamp is patterned after the automobile headlight, with the exception that the bulbs have a filament concentrated as nearly to a point as practicable and located at the focus of the lens, the idea being to concentrate as much as possible of the reflection in a pencil of light, the bright part of which hardly exceeds an arc of two degrees. The air is less disturbed at night and there is less dust and smoke in it; in fact, the observing conditions are at their best in the early part of the night, unless in a section susceptible to nightly fog. With the electric signal lamp, observations were made in 1921 from a station on San Francisco Peak to Ord's Peak and to Green Mountain, Arizona, distances of 153 and 151 miles, respectively, while observations were made on two other lights at distances of over 100 miles simultaneously with the others. All these lights could be seen with the unaided eye throughout the period of observations. (The distances given are all in statute miles.)

Most of the foregoing refers to instrumental observations on artificial objects and not to what can be seen with the unaided eye. On this question there is a great amount of confusion and also some diversity of opinion. There are numbers of cases on record where objects have allegedly been seen with the naked eye much farther than the distances quoted. Our Pike's Peak in Colorado is reputed to have been seen at great distances by travelers in the prairie sections east of it. Travelers in Tibet claim to have seen Mt. Everest from points found to be 400 miles distant, and it has been said that from San Francisco Peak in Arizona one can see into six states and over considerably more than half the entire state of Arizona. Mathematically, it is impossible to see such great distances as these last few, as the curvature of the earth alone precludes such seeing under ordinary conditions, but

we will reserve our doubts somewhat for the future, as it is also well known that certain atmospheric conditions do present strange phenomena and we are thereby able to see objects which are ordinarily considered invisible, as we are about to relate.

An authentic example of this is on record. During the summer of 1911, the officers of the ship *Explorer*, 36 hours out in the Gulf of Alaska from Dixon Entrance to the Shumagin Islands, sighted a group of clear-cut snowclad peaks to the northeastward. The peaks were watched carefully for about 30 minutes, becoming very sharp and distinct and, after examination by compass bearings, were identified as the Fairweather Mountains, which were at a distance, scaled from the map, of 330 miles. The altitude of the highest peak as thus seen was measured and found to be seven minutes above the horizon. Under ordinary conditions the earth's curvature would have obscured the mountains at a distance of about 150 miles. The vision at this long distance can only be explained by refraction, which is known to be very extreme under certain atmospheric conditions in that locality. Refraction is the bending of paths of light passing through layers of atmosphere of different densities. Its tendency is to make the distant object appear too high. Thus we see the sun rise before it actually does.

Another case of unusual refraction was experienced by one of the field parties of the Coast and Geodetic Survey engaged in triangulation in southern Texas in 1917. When first occupying station Towne, which was in the afternoon, the observer noted that station Peters, some 10 miles distant, was obscured by a ridge about midway between the two stations, though to what extent could not be determined. Refraction is greater at night than during the day and, as had been confidently hoped, the light on Peters came out at the usual time at which the light-keepers tend their stations. Observations were begun on this station along with the others, but in a short time the brilliancy of the light began to fade and soon it was lost to view, just after the observations had been completed. It was hoped that the observations in the opposite direction over the line might be made in a similar manner, but no light at all could be seen. After three full days of effort spent in trying to see this light, it finally became necessary to raise both the instrument at one end of the line and the light at the other end 15 feet before observations could be made on what even then was a very dim light due to its grazing the intervening ridge.

Visibility between points on the earth's surface is limited by the curvature of the earth and the meteorological conditions along the line of vision. Curvature, combined with normal refraction, is approximately 5,700 feet at a distance of 100 miles, 22,900 feet at 200 miles and 51,500 feet at 300 miles, and most of the long lines over which observations have actually been made could be observed only by reason of the high mountain elevations with low country intervening. It is well known that dust, haze, smoke and fog greatly obstruct vision, and also that some sections of the country are freer from these than others. It is erroneously thought by some that one can see through these media, at least to some extent, by using powerful telescopes or binoculars; also that one can penetrate distance, and by that means, see much farther than it is possible to see with the naked eye. A telescope has no such magic power, as any particles of matter held in suspension in the air are also magnified in proportion to the power of the telescope, and under many of the extreme conditions such an instrument is almost useless. It is well known among experienced observers that it is

nearly always possible to see the outline of the land where a signal is located with the unaided eye at any time, except at night, that it is possible to make observations. It is generally true that when an object can be seen with a telescope at any distance, an object may also be seen with the naked eye at the same distance, provided the object is large enough. The distinction as regards vision with or without the aid of a telescope is therefore concerned almost entirely with size.

A slightly different case, and one of very common occurrence, is seeing through a boiling atmosphere or one of intense heat waves. When this boiling is intense or close to the observer, it very plainly affects seeing even with the naked eye. With the telescope the motion of the air is magnified and the object under examination may be, under extreme cases, so distorted as to be utterly unintelligible.

Visibility varies greatly with the locality and the meteorological conditions and is consequently rarely constant over any long period. That region in North Carolina and Tennessee so appropriately named "The Great Smoky Mountains," now set aside as a national park, is a region where the average limit to the length of sight is believed to be between 20 and 25 miles. It is very doubtful if 50-mile lines could be observed for as much as 10 per cent. of the time. On the other hand, many sections of the Middle West have such a constantly clear atmosphere that the average limit of visibility is probably between 75 and 100 miles, and frequently much more than this. The condition of the atmosphere has a great influence on visibility, which improves as the elevation increases. In regions near cities or industrial centers visibility is greatly limited by smoke and dust, and near most of our coast line by fog or vapor.

Like almost any specialized work, the expert observer develops his power of understanding and interpretation of what he sees to a fine art. He can observe when others see nothing. It is only another form of that old question "How much do we know of what we see?" One man on the water may view an approaching storm, merely interested in the play of the wind on the water and the fanciful patterned waves thus formed, while another man sees the approaching storm in relation to its probable intensity, the effect it may have on his craft and the havoc it may play on shore. This question of seeing great distances, or in another form, the distances we can see, is therefore a constantly varying quantity. With study one finds as many diverging view-points as with almost any question of the human mind, since any examination of the problem must take into consideration knowledge and experience, ability to interpret, and, in fact, the entire individual background.

A GEOGRAPHIC STUDY OF COSMIC RAYS[1]

By Professor ARTHUR H. COMPTON
THE UNIVERSITY OF CHICAGO

In a recent review of the subject of cosmic rays, Dr. K. K. Darrow describes their study as "Unique in modern physics for the minuteness of the phenomena, the delicacy of the observations, the adventurous excursions of the observers, the subtlety of the analyses, and the grandeur of the inferences." These adjectives are aptly chosen. The cosmic rays are bringing us some important message. What this message may be, we have not, however, learned. Perhaps they are telling us how our world has evolved, or perhaps they are bringing news of the innermost structure of the atomic nucleus.

Attention both of scientific men and of the public was called forcibly to the importance of the studies of cosmic rays by Professor Millikan's suggestive theory of their origin, which he presented at the autumn meeting of this academy seven years ago. He developed the idea that the cosmic rays are produced during the formation of atoms in interstellar space, and presented evidence that this is one stage of a cyclic process through which the universe is continually passing. It will be worth while to dwell for a moment upon this theory and to describe other hypotheses that have been proposed regarding the nature and significance of cosmic rays.

Millikan based his theory on the assumption that the cosmic rays are electromagnetic radiations, or photons, similar in type to x-rays and gamma rays, but of shorter wave-length. This was a natural assumption, in view of the surprisingly great penetrating power which the cosmic rays were found to possess. Considering them to be photons, it was possible to calculate the energy which each individual cosmic ray must have to give it the penetrating power observed in the experiments. On the other hand, he could also calculate the energy liberated by certain types of atomic processes. Thus, if an atom of helium is formed by the sudden combination of four protons and four electrons, the energy liberated is just that necessary to give a photon of penetrating power equal to the least penetrating cosmic rays. The protons and electrons would presumably occur in interstellar space in the form of hydrogen gas. Thus Millikan pictured helium as being formed by aggregations of hydrogen atoms in the intense cold of the space between the stars.

You will recall how Professor Millikan made this process of the formation of helium out of hydrogen one stage in a great cycle. In a similar process it was supposed that heavier atoms, such as oxygen and iron, were likewise formed. The resulting atoms were supposed to come together under gravitational force to produce nebulae and stars. These, in turn, would radiate their energy in the form of photons of electromagnetic radiation. During their passage through space it was supposed that in some unknown manner the energy of these photons would be transformed into electrons and protons, which would be the start of a new cycle.

Immediately following this hypothesis of Millikan's, Sir James Jeans suggested the alternative view that these rays result from the annihilation, rather than from the transformation, of matter. Jeans noted that if they are photons, the

[1] Address before the National Academy of Sciences at Ann Arbor on November 14, 1932.

most penetrating part of the cosmic rays should have just the energy that would be liberated by the sudden coalescence of the electron and proton in a hydrogen atom. That is, whereas Millikan pointed out that the least penetrating cosmic rays have the energy to be expected from the formation of helium atoms out of hydrogen, Jeans found that the most penetrating cosmic rays correspond to the annihilation of hydrogen atoms themselves.

Recently an interesting theory regarding the nature of cosmic rays has been proposed by a young French physicist, Dauvillier. This is not based on the idea of cosmic rays as photons, but rather on the conception that they are electrons shot toward the earth from the sun. This theory is thus somewhat similar to that of Störmer, in which he accounts for the aurora borealis as due to electrons thus shot toward the earth. Dauvillier finds evidence for strong electric fields existing in flocculi on the surface of the sun, estimated at thousands of millions of volts. These powerful electric fields, he supposes, serve to eject the electrons in all directions, some of which would approach the earth. Near the earth they would be affected by the earth's magnetic field and cause at the same time the auroral displays, which are known to be concentrated near the earth's magnetic poles.

It thus becomes clear that before the cosmic significance of these rays can be interpreted, it is necessary for us to test whether the rays are indeed of the nature of photons or of electrons. That is, speaking more generally, are they electrically neutral particles of radiation or some kind of charged particle, such as electrons or protons?

Methods of Distinguishing between Charged and Uncharged Rays

Among the most important methods of distinguishing whether cosmic rays consist of charged or of uncharged particles are the following:

(1) A study of the absorption of the cosmic rays. It is possible to calculate the absorption of electromagnetic radiation in various materials on the basis of a quantum theory. At present the most satisfactory form of this theory is perhaps that proposed by Klein and Nishina some three years ago. Though it is doubtful whether this theory can be considered as a final one, it has been tested experimentally using short wave-length gamma rays, and has been found to fit the experiments reasonably well. There is, nevertheless, danger of error in the use of this formula when extrapolating to wave-lengths much shorter than the gamma rays by which it has been tested. Assuming, however, the validity of the formula, it is possible to calculate what the wave-length must be for a ray of any measured penetrating power. It is on the basis of such an analysis that Millikan's and Jeans' theories have been developed.

The absorption of high-speed electrons can be calculated with a higher degree of certainty on the basis of a formula developed originally by J. J. Thomson and extended to very high energies by Bohr, Swann and others. According to this theory, when an electrified particle passes through matter with a speed closely approximating that of light, its energy is spent in giving impulses to the electrons past which it moves. The effect of these impulses is to produce ions along the path of the high-speed electron. Experiments with x-rays have shown that over a wide range of energies of the high-speed ionizing particle the work required to produce a pair of ions remains nearly the same, about 30 electron volts. Thus the theories of the absorption of these high-speed electrons can be checked by measuring the number of ions produced along the path of an individual ray. Such measurements indi-

cate that the theory in its present form predicts with considerable accuracy the rate at which energy is dissipated by electrons moving with speeds as great as 5×10^8 equivalent volts. It is thus possible to make a definite estimate of the energy of a high-speed electron which will have any assumed penetrating power.

Cosmic rays vary in penetrating power from the comparatively soft ones found only at high altitudes to the very penetrating rays measured by Regener in the deep waters of the Lake Constance. If we suppose that the cosmic rays are electromagnetic in character, their energies should lie between 3×10^7 and 2×10^9 electron volts to give the observed penetrations. If, on the other hand, these rays are high-speed electrons, their penetration corresponds to energies of from 2×10^9 to 7×10^{10} electron volts.

Then comes the problem of accounting for rays having these tremendous energies. The most energetic process that has been proposed for the production of electromagnetic rays is the sudden annihilation of an electron and a proton, as in an atom of hydrogen. This process releases an energy of about 10^9 electron volts. In order to account for the most highly penetrating cosmic rays, then, it is supposed either that Regener's experiments or Klein and Nishina's formula may be somewhat in error for these very penetrating rays, and that the difference of a factor of two between the energy estimated from the experiments and that calculated from the mass of the hydrogen atom really represents a reasonable agreement. On the other hand, the disparity of a factor of seventy between the energy liberated by the annihilation of a hydrogen atom and that required to give an electron so great a penetrating power is certainly greater than the possible errors involved. This would mean that these very penetrating cosmic rays can not be electrons resulting from the destruction of hydrogen. Those who propose the high-speed electron theory, therefore, look to some other source for the energy. Thus, as we have seen, Dauvillier proposes strong electric fields in the surface of the sun. Others have suggested large potential differences in different parts of interstellar space.

(2) There is, however, another aspect of the absorption problem which has been emphasized by Millikan and by Darrow. If the cosmic rays consisted of a homogeneous beam of electromagnetic radiation passing perpendicularly through the earth's atmosphere, we might expect the rays to be diminished in intensity according to a simple exponential law. That such a simple exponential law is not in fact followed is obvious from all the experiments that have been performed. The difference at low altitudes is of the type that might be expected if the incident rays consist of a spectrum of radiation of definite wave-lengths. There is also the fact to be considered that the rays do not strike the earth's surface perpendicularly. They are, rather, moving in all directions.

There is, however, a definite type of difference that may occur in the absorption of photons as compared with the absorption of electrons in the earth's atmosphere. If the rays are of a purely photon type when they strike the surface of the atmosphere, they should produce almost no ionization in an ionization chamber placed at that point. This is because the ions in such a chamber result directly from the passage through the chamber of high-speed electrons or other charged particles. Such high-speed electrons are produced by photons when the photons themselves are absorbed by an atom. The usual result of such absorption is the ejection from the absorbing atom of an electron possessing large part

of the photon's energy and moving usually in nearly the direction of the original photon. Thus, only after the photons have traversed a layer of air so thick that a large portion of their energy will have been transformed into the high-speed electrons, will it become possible to measure the rays by means of an ionization chamber. It thus becomes apparent that near the surface of the atmosphere photons entering the air should produce little effect; but as the ionization chamber is brought lower down into the air, there will be some position at which the intensity of ionization will become a maximum. At lower altitudes the cosmic rays will have become so strongly absorbed that the ionization will become less, and will from there on be reduced in a nearly exponential manner as the chamber is brought to lower and lower altitudes.

High-speed electrons, on the other hand, produce ions of nearly the same number per unit path until they have reached nearly the end of their range. If we suppose that the rays striking the surface of the earth's atmosphere are purely electronic in form, ionization should thus be strong at the surface of the atmosphere. We should expect the current in an ionization chamber to remain approximately constant if the chamber should be carried downward from the surface of the atmosphere, until it reaches such depths that an appreciable number of the original electrons are stopped by absorption in the atmosphere.

If the rays approaching the earth are photons, an ionization chamber should accordingly record almost no current near the top of the atmosphere. If the incident rays are electrons, the current in the chamber should approach a gradual maximum near the top of the atmosphere. It is in the attempt to see whether either of these alternatives is in accord with fact that the recent high altitude mountain and balloon measurements have been made. These experiments, as we shall see, have supported the incident electron view.

(3) An experiment which was at first thought to give decisive evidence that the cosmic rays consist of electrons was carried out some three years ago by Bothe and Kolhörster. We have remarked that whatever may be the character of the primary cosmic rays, the ionization currents that are observed in our experiments are directly due to ions produced by high-speed electrical particles. It is possible to devise an electroscope so sensitive that it will respond to the ionization produced by a single such high-speed particle. Such an instrument is known as an ion counter. Bothe and Kolhörster arranged two such counters, one over the other, as indicated in Fig. 1.

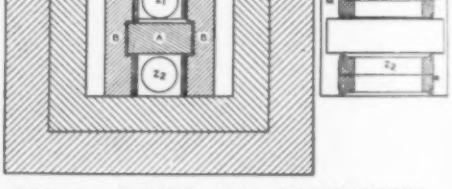


FIG. 1. BOTHE AND KOLHÖRSTER APPARATUS

FOR MEASURING THE ABSORPTION OF PARTICLES PASSING BETWEEN TUBES Z_1 AND Z_2 THROUGH THE BLOCK OF GOLD *A*.

The two counters were so connected that if ions were produced simultaneously in both chambers, a record would be produced. No record, however, would result from ions formed in only one of the two chambers. Thus, if a high-speed particle should pass directly through both chambers it would be recorded by their instrument. It was found that if

one counter was placed over the other, as in this drawing, frequent coincidences were observed. If, however, they were placed at an equal distance, but side by side, such coincidences were rare. This indicated that the high-speed particles that were being recorded were traveling in a nearly vertical direction.

Bothe and Kolhörster now placed between their counters a heavy block of gold to absorb and, if possible, stop the high-speed particles from passing through both counters. If the particles were thus stopped there should, of course, occur no coincident impulses in the two chambers. It was found, however, that a block of gold as thick as four centimeters still allowed most of the particles to pass through. The experiment has more recently been repeated by Rossi, using a block of lead 30 inches thick, and he still observed a considerable fraction of the coincident impulses that occurred with no absorbing screen. When the absorbing block was placed over the upper counter the reduction in coincidence counts was almost the same as when placed between the two counters. This meant that the absorption of the high-speed particles passing through the two counting chambers was very nearly the same as the absorption of the cosmic rays which produced the high-speed particles.

The most obvious interpretation of this experiment was to suppose that the high-speed particles that were being counted were the cosmic rays themselves. Millikan pointed out, however, that what the experiment really showed was that these high-speed particles are absorbed at very nearly the same rate as are the cosmic rays, and he suggested that at very high energies the rate of absorption of a photon may be almost indistinguishable from the absorption of the recoil electrons which it knocks out of the atoms through which it passes. A recent detailed study by Heisenberg shows, however, that it is very difficult to reconcile Millikan's suggestion with the theory of absorption of photons and electrons. If Millikan's suggestion were correct, it would mean that an electron having the same energy as a photon should be absorbed less rapidly by air. The theories of absorption seem to predict definitely that the electron must always have the greater absorption. These experiments with the counting chambers thus give evidence so direct in favor of the hypothesis of cosmic rays as electrons that this possibility must be given careful consideration.

(4) Perhaps the most direct method of distinguishing between charged and uncharged particles in motion is to see whether they are deflected by a magnetic field. By this method, for example, it was first shown that cathode rays are negatively charged, resulting in the identification of the electron.

Several investigators have attempted to deflect cosmic rays by means of great magnets. Among the first of such attempts was one by Curtis, in which he studied the coincident discharges in a pair of ion counters when a powerful electromagnet was placed between the counters. He observed a small but definite effect. Later experiments by Mott-Smith and at about the same time by Rossi, both of whom allowed the cosmic rays to traverse an iron core of the electromagnet, showed no effect. Within the past year Anderson, working with Millikan at Pasadena, has studied the tracks produced by cosmic rays in a cloud expansion chamber.

Fig. 2 (see p. 81) shows a typical photograph. There can be seen a fine line of fog droplets marking the trail of a particle which traversed the chamber at high speed. The slight curvature is due to the action of the powerful magnetic field in which the chamber was placed.

Supposing that the particle is moving downward, the direction of curvature is appropriate to a negatively charged particle. There also occur in these photographs similar tracks which seem to be due to positively charged particles. There is thus an effect produced by a magnet on the cosmic rays.

It is not clear from experiments of this kind, however, whether the trails which are being photographed are those of the primary cosmic rays or whether they may be secondary electrons produced by the primary rays. Thus, we have not been able by such experiments to determine the nature of the primary cosmic rays themselves.

(5) For studying the original rays, it would be necessary to have a magnet so large that it would affect the rays before they reach the earth's atmosphere. This, however, is exactly what we have in the earth itself, which of course acts as a huge magnet. With this in mind, several investigators have made studies of the strength of the cosmic rays at different points on the earth in the attempt to find whether these rays are affected by the earth's magnetic field. Theoretical studies by Störmer and Epstein have shown that if the cosmic rays are electrons shot at the earth in all directions from remote space the earth's magnetic field will prevent all the rays from striking its surface, except in the neighborhood of the magnetic poles. Even for initial energies as great as 10^9 electron volts the electrons would strike the earth only within some 30° of the magnetic poles. Such calculations suggested that the effect of the earth's field, if any, should be most strongly observed in the polar regions.

Accordingly, Millikan took his cosmic ray electroscope from Pasadena to Churchill on Hudson's Bay, near the north magnetic pole. Bothe and Kolhörster took their counting chamber from Hamburg up to Spitzbergen and back. Kerr Grant sent Kennedy from Australia to the Antarctic with a cosmic ray counting chamber. Corlin traveled in different parts of Scandinavia, where the earth's magnetic field changed in intensity. Only one of this first group of investigators studied the ray near the equator. This was Clay of Amsterdam.

On bringing together their results, it was found that although Clay and Corlin had both seemed to detect effects which they considered greater than experimental error, the other investigators failed to find any detectable differences that could be ascribed to the earth's magnetic field.

World Survey of Cosmic Rays

Before our theories regarding the origin and significance of the cosmic rays could be developed further, it was clear that we must, if possible, find out their nature. Though Bothe and Kolhörster's double counter experiment had given a strong indication that the rays were electrical in character, the failure in these preliminary experiments to find any definite connection between the earth's magnetic field and the intensity of the cosmic rays in different parts of the earth left their nature in doubt. It seemed that by far the most significant study that could be made of this question would be an extensive survey of the strength of the cosmic rays in different parts of the earth. Some fifteen months ago we accordingly undertook such a survey with the support of the Carnegie Institution. Our principal objectives were, (1) to obtain as extensive information as possible regarding the distribution of cosmic rays over the earth; (2) to study the variation in intensity of the cosmic rays with altitudes in different locations; and (3) to see whether there exists any difference between the cosmic ray radiation in daytime and at

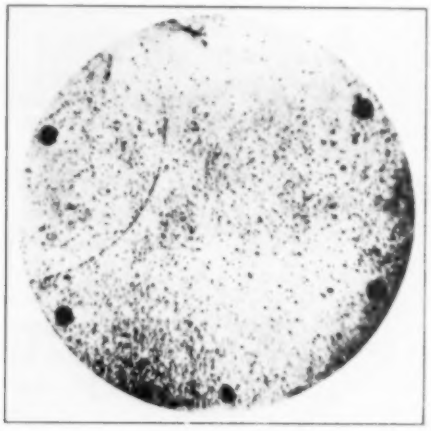
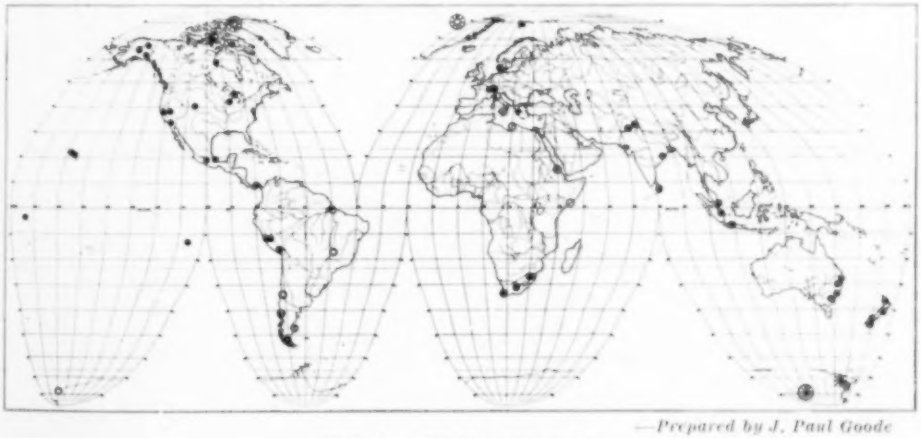


FIG. 2. ANDERSON'S PHOTOGRAPH
OF THE PATH OF AN ELECTRON ASSOCIATED WITH COSMIC RAYS.

night. It was hoped that the information thus obtained, added to that which had been gathered by other methods, would enable us to give a reasonably definite answer to our question as to the nature of the rays.

It was, of course, necessary in a program of this kind to get the extensive cooperation of a large number of physicists. Our invitations to join this work met with an enthusiastic response. In order to make a reasonably complete survey within a brief period, the globe was portioned into nine regions, each of which was assigned to a different investigator. In charge of these various expeditions were the following men, each of whom has been responsible for the results obtained by his own party:

(1) Professor Ralph D. Bennett, of the Massachusetts Institute of Technology, whose



—*Prepared by J. Paul Goode*

FIG. 3. SOLID CIRCLES
ARE STATIONS WHERE MEASUREMENTS BY OUR ASSOCIATED EXPEDITIONS HAVE BEEN COMPLETED. OPEN CIRCLES REPRESENT PROJECTED MEASUREMENTS. MEAN MAGNETIC POLES IN CIRCLES. LOCAL POLES WITHOUT CIRCLES.

party has studied Alaska, California and Colorado.

(2) Dr. E. O. Wollan, of the University of Chicago, who has made measurements in Chicago, Spitzbergen and Switzerland.

(3) Dr. D. la Cour, director of the Danish Meteorological Survey, whose expedition is now working in northern Greenland at the north pole of the earth's uniform magnetization.

(4) Mr. Allen Carpe, research engineer of the American Telephone and Telegraph Company, whose ill-fated expedition made measurements on Mount McKinley, Alaska.

(5) Professor J. M. Benade, of Punjab University, who has worked in India, Ceylon, Java and Thibet.

(6) Professor S. M. Naude, of the University of Cape Town, now working in South Africa.

(7) Mr. P. G. Ledig, in charge of the Carnegie Magnetic Observatory at Huancayo, Peru, who is just preparing to start from Peru around Cape Horn and back by way of Brazil to the United States.

(8) Admiral Byrd and his associated physicist, Professor Poulter, of Iowa Wesleyan University, who plan to continue these studies in Antarctica.

(9) My own branch of the expedition, which has worked in Switzerland, Colorado, Hawaii, New Zealand, Australia, Peru, Panama, Mexico, northern Canada and northern United States.

Accompanying these leaders there have been some fifty other cooperating physicists, who have worked intensively for periods of from a few days to several months to help in completing the survey. A glance at the world map will indicate how these expeditions have attempted to cover representative portions of the earth's surface.

Following the lead of earlier investigators and the theoretical predictions of Epstein, the most detailed attention of these expeditions was directed to the north and south magnetic polar regions. If one knew beforehand the result of an experiment there would be little value

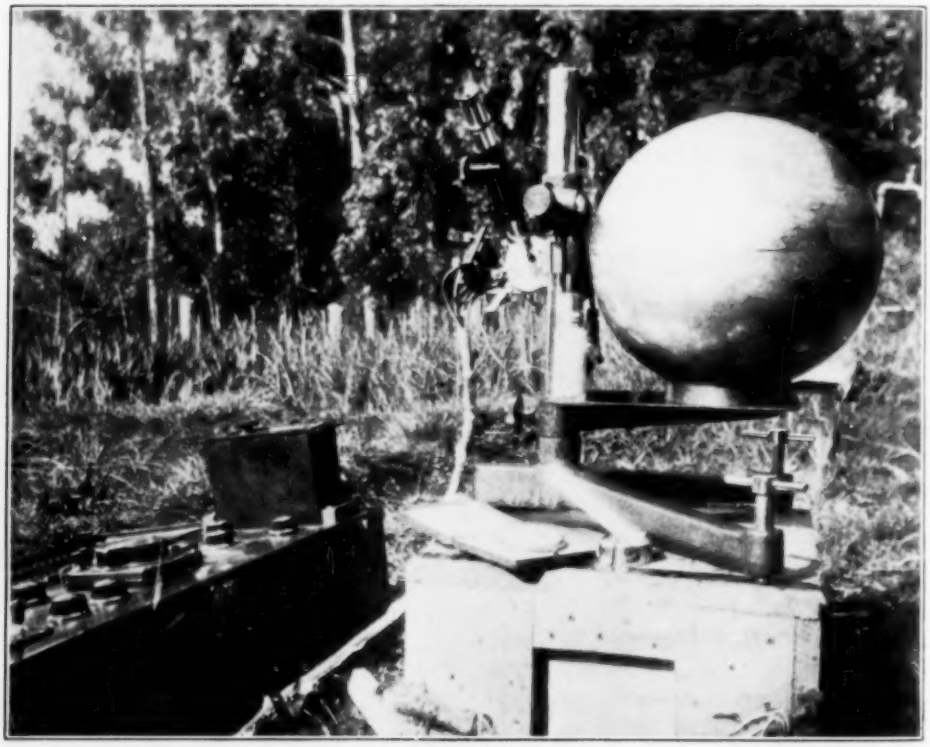


FIG. 4. COSMIC RAY APPARATUS AS USED IN FIELD MEASUREMENTS.

in performing that experiment. Thus, in planning this work, had we known that the interesting results would be found near the equator, our apportionment of the various trips would have been made in a very different manner. Our measurements showed very little, if any, variations near the magnetic poles, but quite marked differences in the equatorial regions.

The apparatus used in this survey is shown in Fig. 4 on page 82. It consists of a spherical steel ionization chamber, filled with argon gas at thirty atmospheres pressure, and connected with a Lindemann electrometer, which measures the ionization current. Heavy spherical shells of lead and copper protect the ionization chamber from gamma rays from local sources. For standardizing the measurements, a capsule containing a small quantity of radium is placed one meter from the center of the ionization chamber. The gamma rays entering the chamber serve as a standard relative to which the cosmic rays can be measured at any location. There is always a certain amount of ionization due to radioactivity in the ionization chamber itself. For three of the eight sets of equipment this has been measured by carrying each set into a tunnel where it was shielded by 1,000 feet or more of rock.

In Fig. 5 is shown a group of curves representing the variation of the intensity of the cosmic rays with altitude as we have found them in different locations. In this slide has been included all the data so far reported by our various expeditions. It will be seen that all the curves have a similar shape, representing rapid increase in intensity with altitude. It will be noticed also, however, that the lowest curves are all taken in tropical regions and the highest curves in temperate or polar regions. Knowing the shape of the altitude intensity curves, the value at sea-level

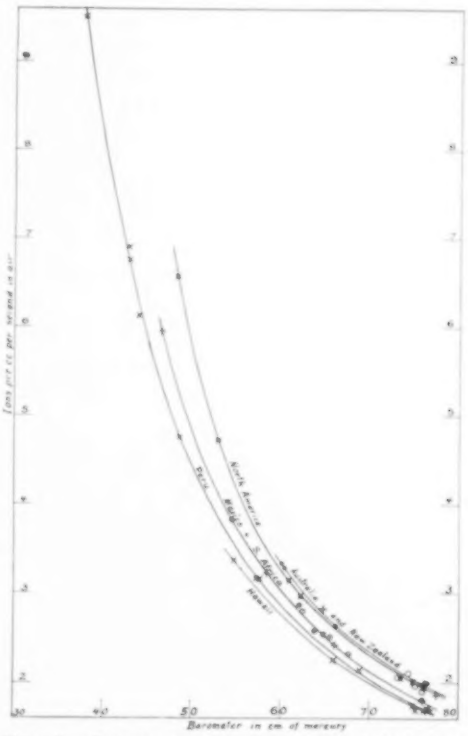


FIG. 5. INTENSITY OF COSMIC RAYS AT VARIOUS ALTITUDES AS OBSERVED IN VARIOUS PARTS OF THE WORLD.

corresponding to the observed intensity at any level corresponding to the observed intensity at any other altitude can be estimated. Thus we can plot these data against the latitude if we reduce each observation to its equivalent value at some standard altitude, such as sea-level.

Fig. 6 shows the data, thus reduced to sea-level values, plotted against the geographic latitude. In general, it is clear that the low latitudes show less intensity than do the higher latitudes. There is, however, considerable variation from the smooth curve drawn through the experimental points. When, on the other hand, we plot the sea-level intensity against the magnetic latitude, as shown in Fig. 7, it will be seen that the data fall more nearly upon a smooth

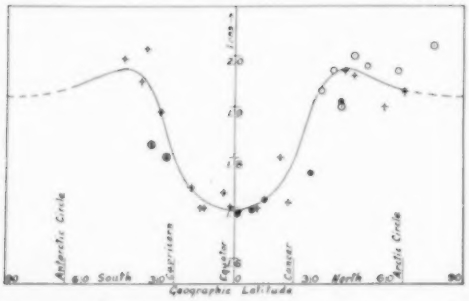


FIG. 6. INTENSITY OF COSMIC RAYS AT SEA LEVEL, AT LATITUDES FROM 44° S TO 78° N, AS MEASURED BY VARIOUS OBSERVERS, SHOWING MINIMUM NEAR THE EQUATOR.

curve. This magnetic latitude is taken as the distance from the magnetic equator drawn between the poles of the earth's uniform magnetization, and thus represents the effect of the earth's field as observed at some distance from its surface.

It would seem from these data that a definite variation occurs in the intensity of cosmic rays for different positions in the earth's magnetic field. Though in northern and southern latitudes the intensity would seem to be very nearly uniform, in equatorial regions there is a marked minimum. What interpretation can be given to such a variation? It is obvious that such a magnetic effect must mean that there are electrically charged particles

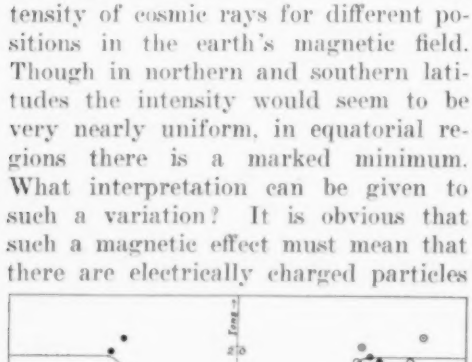


FIG. 7. WHEN PLOTTED AGAINST THE MAGNETIC LATITUDE, THE INTENSITY OF THE COSMIC RAYS FALLS MORE ACCURATELY ON A CURVE THAN WHEN PLOTTED AGAINST GEOGRAPHIC LATITUDE, AS IN FIG. 6.

associated with the cosmic rays. Are these particles, however, the primary rays or secondary rays produced by the primary rays?

SIGNIFICANCE OF THE VARIATION WITH MAGNETIC LATITUDE

A definite answer to this point would seem to be given by a consideration of the conditions under which the earth's magnetic field can produce an appreciable curvature in the path of a high-speed electron. If such curvature is to be appreciable, the distance that the particle travels before being stopped by the earth's atmosphere must be sufficiently large. If this range is short compared with the radius of curvature of the path of the particle, the path will be nearly a straight line, that is, the earth's magnetic field will have no appreciable effect. Now the path of an electron moving at high speed in a magnetic field has a radius of curvature proportional to the energy. On the other hand, the range in air of a high-speed electron is likewise, according to current theories, proportional to the energy of the particle's motion. Thus for these high-speed particles there is a definite ratio of range to radius of curvature, which is independent of the particle's energy. At atmospheric pressure it can be shown that the radius of curvature should be about 25 times the range of a high-speed electron. This would mean that at atmospheric pressure the curvature produced in the path of an electron by the earth's magnetic field should be negligible. If, however, we go to an altitude of say 15 miles where the density of the earth's atmosphere is about 1/25 of that at sea-level, the range of an electron should be about equal to its radius of curvature, and under these conditions the earth's magnetic field should have an appreciable effect. It thus becomes evident that a variation in intensity of the cosmic rays

with the earth's magnetic field means that associated with these rays are electrons (or at least electrified particles) which originate at an altitude of not less than 15 miles.

Supposing that it is these electrons originating high in the earth's atmosphere which are detected by our ionization chambers at the earth's surface, an investigation of the energy necessary for the particles to penetrate the atmosphere indicates that they must start with an energy not less than several billion electron volts. This would give them a radius of curvature in the earth's magnetic field of the order of at least some hundreds of miles. Thus, our magnetic data can be satisfactorily explained if we suppose that the cosmic rays originate as high-speed electrons high in the earth's upper atmosphere. Such a region of origin would be approximately the same as that at which the auroral displays occur. Associated with such high-speed electrons there would also be produced rays of the photon type; that is, x-rays of very short wave-length. These rays might well constitute those which are observed by Regener at very great depths in water.

A possible alternative to this interpretation would seem to be that the electrons reaching the earth enter from remote space with energies so great that they are not very strongly affected by the earth's magnetic field. From Epstein's calculations this would mean that they must have an initial energy of the order of 10^{10} electron volts.[2]

Variation with Altitude

In various locations our expeditions have made a special study of the variation in the intensity of cosmic rays with altitude. Perhaps the most satisfactory results have been those obtained in Peru and in Thibet. Fig. 8 shows a comparison of our data obtained at two different locations in Peru with those found recently in the balloon flights of Piccard and Regener. For convenience the intensities are plotted logarithmically. If the rays are homogeneous and have a definite absorption coefficient the data on such a plot should lie on a straight line. An upward curvature would indicate a lack of homogeneity of the incident rays. That is, some would be of a more penetrating type than others. A downward curvature would mean that the rays are not absorbed in the statistical manner appropriate to photons or electromagnetic radiation. It is clear from this figure, as Regener has pointed out in connection with the result of his balloon flight, that at very high altitudes the intensity of the rays approaches a constant value such that for appreciable differences in air pressure there is no appreciable change in the intensity of the cosmic rays.

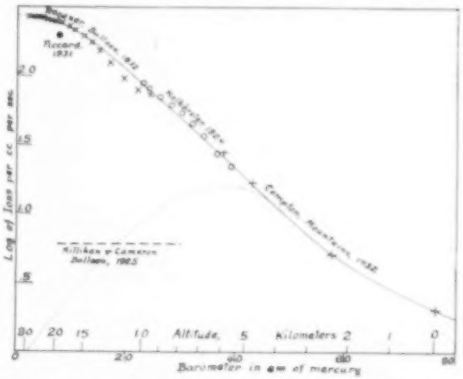

Piccard, 1931
Millikan & Cameron, Bolivian, 1925
Millikan & Cameron, Peruvian, 1926
Millikan & Cameron, Bolivian, 1925
A. Compton, Mountains, 1932
Log of Ions per cc. per sec.
2.0
1.5
1.0
.5
30 20 15 10 Altitude, 5 Kilometers 2 1 0
0 20 40 60 80
Barometer in cm of mercury

Fig. 8. Intensity of cosmic rays at high altitudes, showing asymptotic approach to maximum at surface of atmosphere, as expected if cosmic rays are ionizing particles.

A consideration of the possible interpretation of this result is of interest. If we suppose that the cosmic rays enter the earth's atmosphere as photons, any

[2] Since this was written, the manuscript of a new theory by Le Maitre and Vallarta has been shown me, from which it appears that electrons of less energy than 10^{10} electron volts can reach the earth from remote space. The predictions of their theory, based on electrons from remote space, agree very well with the data shown in Fig. 7.

secondary electrons that may have been associated with them will have been removed far above the atmosphere by the action of the earth's magnetic field. We should thus have a beam of pure photons entering the atmosphere. As has been indicated above, at the surface of the atmosphere these photons will produce very little ionization. The ionization current should rather approach a maximum at a depth in the atmosphere at which the cosmic rays are about half absorbed, and should then gradually diminish in intensity as sea-level is approached. Some early sounding balloon measurements of Millikan and Bowen indicated that such an effect did indeed occur, and this was used as evidence for the photon character of the rays. Our high mountain experiments, however, confirm the more recent balloon experiments as indicating that no high altitude maximum, such as these early experiments suggested, exists. This would seem to rule out the possibility that the cosmic rays can be photons entering the earth's atmosphere from remote distances.

If we suppose, on the other hand, that the cosmic rays are electrons entering the atmosphere from above, we should expect very much the kind of intensity altitude curve that is here shown. Thus, supposing that the cosmic rays consist of electrons originating more than a hundred miles above the earth's surface and going from there in all directions, the general characteristics of the intensity altitude curve can be readily accounted for.

This view is strongly supported by an observation of Piccard on his recent balloon flight. He had with him a pair of ion counters so arranged that it was possible to distinguish the direction from which the ions entered his gondola. He reports that within experimental error, which was in his case less than 1 per cent., there was no difference between the number of rays passing horizontally and those passing vertically. This is in striking contrast to similar tests made at sea-level, where the number of cosmic rays traversing the counters when arranged vertically is greatly in excess of those traversing them when placed in a horizontal direction. This observation, Piccard believes, supports the view that the cosmic rays originate in the part of the earth's upper atmosphere where his balloon was floating.

Diurnal Variation

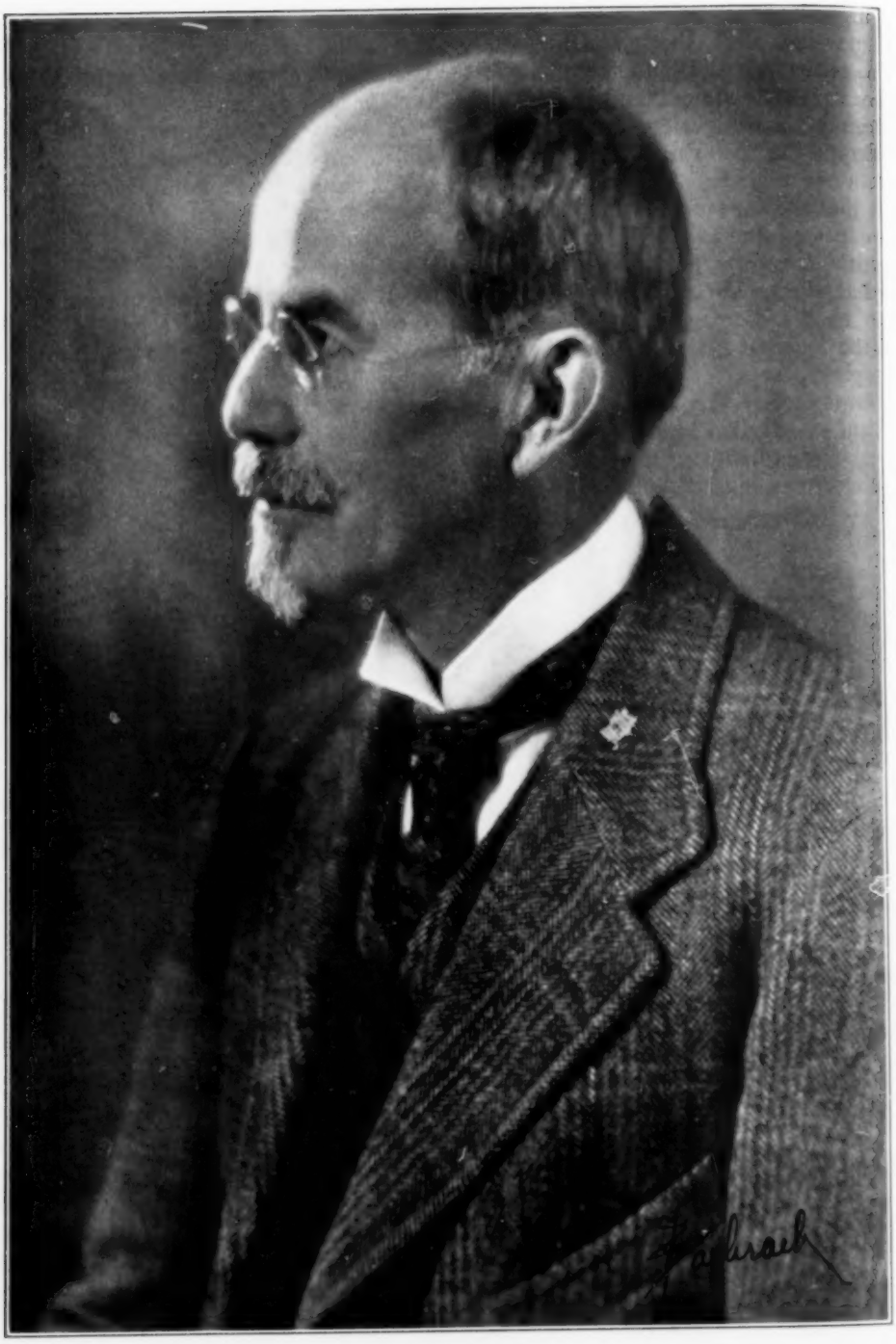
Ever since the early studies of cosmic rays by Hess, the question of their constancy at different times of day has been discussed. Though the relatively large variations at one time noted by Kolhörster have since been attributed to statistical fluctuations, more detailed studies have almost always shown a very slight preponderance of the radiation in the daytime as compared with the night. According to Hess, this difference at sea-level is of the order of .3 to .5 per cent. Millikan has reported differences of the same order of magnitude, but considers them within experimental error. Along with our other studies, we have also made an investigation of this point, although our apparatus was not large enough to make measurements with the statistical precision that would have been desirable for the purpose.

The result has indicated differences which are probably real and of higher magnitude than those found by other observers. Our measurements, however, have been made at higher altitudes. Professor Bennett and Dr. Dunham, working at the Arctic circle in Alaska, found no detectable difference whatever between day and night. In Colorado, at an altitude of 13,000 feet, we found an effect of the order of magnitude of one per cent. In Peru, at an altitude of 15,000 feet, the intensity in the daytime was about 2 per cent. greater than that

at night, though the probable error was comparable with the observed effect. This seems to indicate a maximum effect where there is a maximum contrast between day and night conditions.

Supposing that these observed differences are real, Ross Gunn has pointed out that they are of the type that would be expected due to the difference in the earth's magnetic field in the daytime and at night. He considers the effect as due to the diamagnetic characteristics of the ionized regions of the upper atmosphere, an effect which is greater at high altitudes than at relatively low altitudes. If this interpretation is correct, it would suggest that the origin of the electrons must be as high as a hundred miles or more above the surface of the earth, thus confirming the estimate made on the basis of the effect of the earth's magnetic field.

It would thus appear that the data which have been obtained in this geographical study of cosmic rays may be satisfactorily explained if we suppose that the cosmic rays consist of electrons, originating at least some hundreds of miles above the surface of the earth. Whether the point of origin is in the earth's upper atmosphere or in remote space has not yet been determined. It seems necessary, however, to suppose that at least the major part of the rays consist of electrically charged particles rather than photons or neutrons.



DR. JOHN J. ABEL

EMERITUS PROFESSOR OF PHARMACOLOGY, THE JOHNS HOPKINS UNIVERSITY; PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE ATLANTIC CITY MEETING OF THE AMERICAN ASSOCIATION

ALWAYS mindful of its responsibilities toward those whose activities are concerned with the more or less highly specialized lines of science, the association of late years more and more has come to serve as a forum for the discussion of the broader bearing of scientific truths in their relation to human welfare and to human labors.

Progress in science is dependent upon two interallied factors. First of all, facts must be determined. But dissociated and disconnected facts, though always interesting, are of little value. In order to become of value, facts must be correlated and coordinated and assigned to their proper place in their relation to other facts, becoming thereby an integral part of the structure of science as a whole.

The proper appreciation and allocation of the facts accumulated by work in the specialized lines of science is hastened by the critical examination and discussion of these facts, and their broad dissemination. Once properly appraised, it becomes possible to apply them to the good of the people as a whole.

The accumulation of the basic facts of science and their exposition and discussion for the most part falls within the scope of one or other of the one hundred and thirty-seven societies, representing all fields of science, which are affiliated with the association. Many of these societies will meet with the association at Atlantic City. The programs of those that will meet at Atlantic City are both unusually full and exceptionally interesting.

In addition to the more or less strictly technical papers there are included in the programs of most of the sections and societies addresses of more general scope,

THE MUNICIPAL AUDITORIUM

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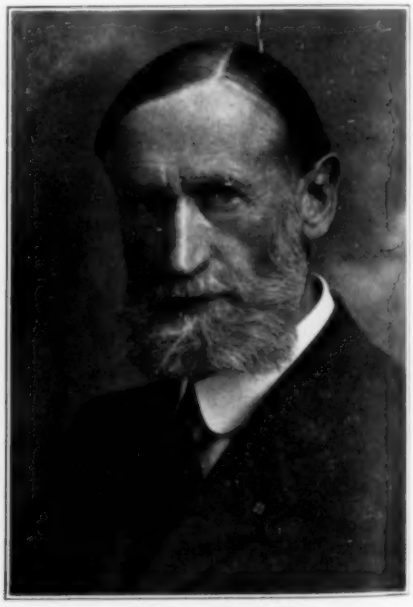
DEAN OF THE SCHOOL OF CHEMISTRY AND PHYSICS, PENNSYLVANIA STATE COLLEGE; CHAIRMAN OF THE SECTION OF CHEMISTRY.

DR. PAUL W. MERRILL

ASTRONOMER, MOUNT WILSON OBSERVATORY; CHAIRMAN OF THE SECTION OF ASTRONOMY.



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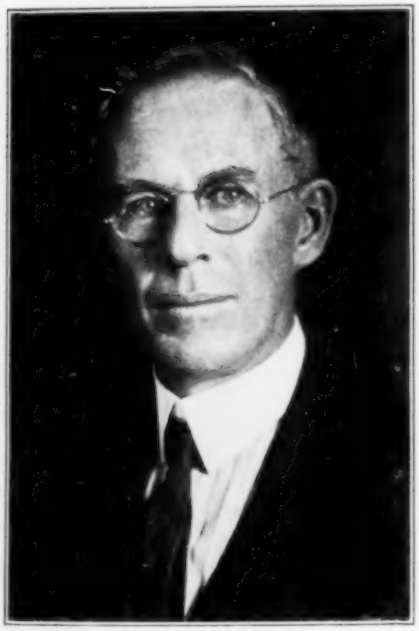

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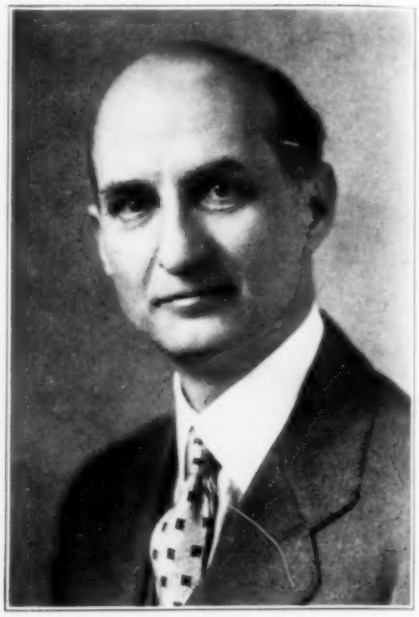
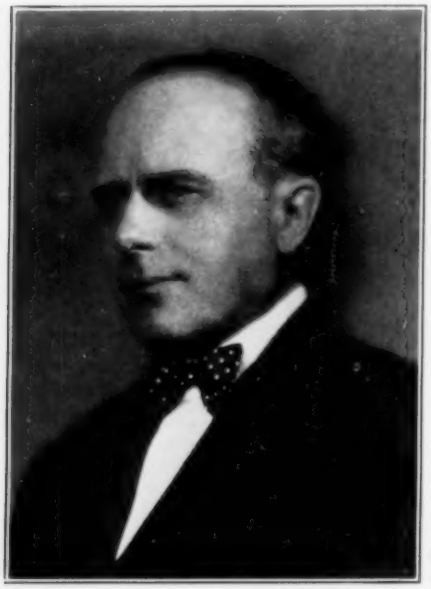
DR. WILLIAM F. OGBURN

Professor of Sociology, University of Chicago; Chairman of the Section of the Social and Economic Sciences.



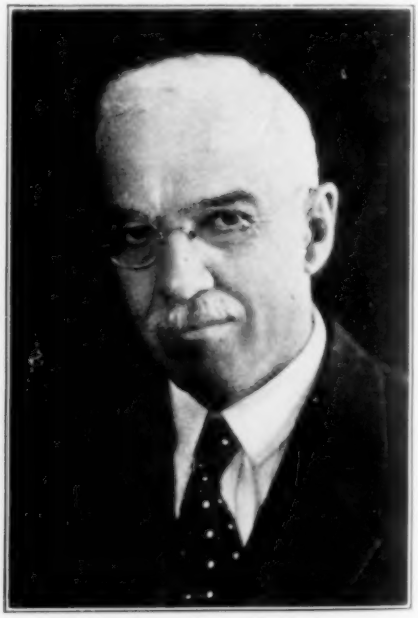
J. H. GOURLEY

Professor of Horticulture, Ohio State University; Chairman of the Section of Agriculture.



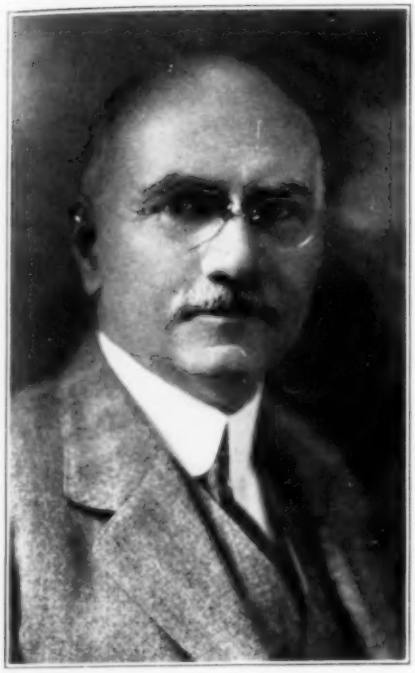
DR. WALDO G. LELAND

Permanent Secretary of the American Council of Learned Societies; Chairman for the Historical and Philological Sciences.



PROFESSOR WM. H. PARK

Director, Health Department of the City of New York; Chairman of the Section of the Medical Sciences.



DUGALD C. JACKSON

PROFESSOR OF ELECTRICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; CHAIRMAN OF THE SECTION OF ENGINEERING.

and thus of interest especially to those with a general knowledge of the subject as a whole.

A large number of symposia have been arranged covering a wide range of subjects. The program for Section N (Medical Sciences) will be devoted entirely to symposia. In Section B (Physical Sciences) there will be a symposium on cosmic rays in which Dr. Robert A. Millikan, Dr. Arthur H. Compton, Dr. W. F. G. Swann and others will participate. Another interesting symposium will deal with the late Pleistocene and recent changes of level along the Atlantic coast of North America. Of timely interest is a symposium in Sections K (Economics, Sociology and Statistics) and M (Engineering) on the stabilization of employment, and another on radio problems.

The association has been especially fortunate in having been able to arrange an unusually representative series of general lectures for the Atlantic City meeting. Eminent speakers will discuss subjects in the fields of anthropology, mathematics, chemistry, physics, botany, zoology, meteorology, astronomy, sociology, dentistry and engineering.

The first general evening lecture will be given by Dr. Franz Boas, the retiring president of the association, who will speak on "Anthropology and Its Aims." This address will be followed by a general reception. Other general lectures will be on "The Social Effects of Mass Production," by Professor Dexter S. Kimball, "The Constitution of the Stars," by Dr. Henry Norris Russell, "Thermodynamics and Relativity," by Dr. Richard C. Tolman, and "Personal Experiences in West Indian Hurricanes," by Dr. Mel T. Cook. And there will be others equally interesting.

AUSTIN H. CLARK

DR. S. A. COURTIS

PROFESSOR OF EDUCATION, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION OF EDUCATION.

DR. IRVING LANGMUIR

DR. LANGMUIR, RECIPIENT OF THE NOBEL PRIZE IN CHEMISTRY

IRVING LANGMUIR was born in Brooklyn, New York, on January 31, 1881, and was graduated from Columbia University in 1903 with the degree of metallurgical engineer, after which he spent three years in postgraduate work at the University of Göttingen, taking his Ph.D. degree under Nernst. He returned to the United States in 1906 and became an instructor in chemistry at the Stevens Institute of Technology. Three years later he entered the research laboratory of the General Electric Company in Schenectady, New York, where he is at present associate director, and where his valuable contributions to science and industry have been made. During this time he has received many honorary degrees and other honors from universities and scientific societies, the latest being the Nobel Prize, awarded in chemistry, for the year 1931, by the Swedish Academy of Sciences.

The research of Dr. Langmuir has covered an exceedingly wide range of subjects in physics and chemistry, both theoretical and applied. He is so much at home in both these scientific fields, as well as in their industrial application, that he wanders freely from one to the other, completely ignoring their traditional boundaries, and one is not sure whether his purely scientific work was stimulated by the industrial work with which he has been associated, or whether it has been the purely scientific work that has stimulated his applications of science to industry. The laboratories with which he is associated have given him ample opportunity to follow his genius. Nearly every field in which he has done research has both scientific and practical significance. A partial list of the subjects which he has most thoroughly investigated is as follows: surface phenomena; chemical reactions at very low pressures; the production and properties of atomic hydrogen; the emission of electrons from heated filaments; valence and the conductivity of electricity in gases. Many of these investigations involved first devising new experimental techniques before the problems themselves could be approached successfully. His outstanding inventions include the gas-filled incandescent lamp, a hydrogen welding torch, a very rapid high vacuum pump, as well as many other improvements in the field of electricity and chemistry.

In 1912 he published his first paper an atomic hydrogen, and with the exception of the discovery by Professor R. W. Wood that atomic hydrogen could be removed from electrical discharge tubes and pumped for considerable distances away from them, almost the whole development of atomic hydrogen has been the result of his pioneer work. His early papers deal with the heat of decomposition of molecular hydrogen into atoms, and, though the value secured was not as exact as values which have been determined since then by more reliable methods, his work was an outstanding accomplishment at the time. The invention of the hydrogen welding torch was the result of correlating the work of Wood with his own observations and gave us an exceedingly high temperature reducing flame for the welding of metals.

His work in the field of surface phenomena appeals to the writer as being the most outstanding development in this field since the classical work of Gibbs. Nearly the whole development in the field of adsorbed films of gases on metallic and other solid surfaces, from the time when Langmuir published his first papers in 1915, has been the result of his thoroughgoing investigation of the subject. He established conclusively that the adsorbed film of substances is monatomic or monomolecular. This he demonstrated very nicely in the case of films of organic substances on liquids, in the case of such things as oxygen and hydrogen adsorbed on metals such as

tungsten and platinum. Recently he has succeeded in laying down a single atomic layer of oxygen on tungsten and a succeeding layer of cesium on top of this oxygen layer. He has devised methods of detecting these films, studying the rate at which they are formed and the rate at which atoms deposited on a surface diffuse over the surface. To appreciate the difficulties encountered in this surface work, one needs to recall that the mass of substance required to form a monomolecular film even over a considerable surface is very small, and much of this work of Langmuir was only possible after devising adequate experimental methods. The theoretical development has been no less outstanding. He has interpreted the experimental data in these fields from the standpoint of two-dimensional gases and liquids and has applied phase rule considerations to them.

Much of the work that Langmuir himself has done, and which is now being done in chemical and physical laboratories the world over was made possible by the invention of a piece of apparatus which now appears to us as being very common and ordinary. High vacua had been secured before Langmuir invented his mercury pump. Some of the pumps known previously up to this time operated upon principles that were at least similar to those used by Langmuir, but the speed of the pump which he devised has been so great that now we secure high vacua in our physical laboratories with the greatest ease.

Two sources of emotional motive power for pure and scientific research are present to a greater or less extent in all scientific workers. They are prompted by an intense curiosity in regard to the way nature behaves and a desire to know the relationships that exist between physical phenomena. This is the attitude of the pure scientist. On the other hand, they also have a desire to see the results of their scientific work made useful to the end of eliminating want, hard labor and the bringing of a high plane of comfort and luxury to people in general. Langmuir has responded to both of these impulses, and though the Nobel Prize is awarded for pioneer work in pure science, no review of the work of Irving Langmuir would be complete without a mention of his contribution to the applied sciences.

One of his first problems of research after he entered the General Electric laboratories at Schenectady was on the newly invented drawn tungsten filament lamp, which was then of the vacuum type. The glass rapidly became darkened, thus cutting down the illumination, and the filament disintegrated. Langmuir investigated the fundamental causes of these defects and found that they were two in number: first, the tungsten evaporated from the filament, causing disintegration of the filament, and the deposition of a black layer on the inside of the glass surface; and second, traces of water vapor in contact with the hot filament led to disintegration of the filament and a deposition of a black deposit on the glass surface. Langmuir overcame these defects by filling the bulb first with nitrogen gas, which greatly improved the life and brilliancy of the lamp, and later, for special types of lamps, with argon gas. The intensity of illumination from such lamps from the same consumption of power is two or more times as great as it would be without the improvements which he devised.

Another of the recent developments of applied science to which he has contributed in an outstanding way is the thermionic vacuum tube used so extensively in radio. The development of these tubes has been very closely tied up with his work on surface phenomena as applied to the filaments in these tubes, to the conduction of electricity by gases, to which he has contributed in so many ways, and to the securing of adequate and satisfactory vacua for their operation. A large share of the credit for the perfection of these tubes goes to Irving Langmuir.

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